AFHRL-TR-90-67

AD-A243 225

FACTOR ANALYTIC EXAMINATION OF THE ARMED SERVICES VOCATIONAL APTITUDE BATTERY (ASVAB) AND THE KIT OF FACTOR-REFERENCED TESTS

HUMAN RESOURCES

Werner Wothke
R. Darrell Bock

Scientific Software, Incorporated
Technical Operations Division
1525 E. 53rd Street, Suite 830
Chicago, Illinois 60615

Linda T. Curran

MANPOWER AND PERSONNEL DIVISION
Brooks Air Force Base, Texas 78235-5601

Benjamin A. Fairbank

Operational Technologies Corporation
5825 Callaghan Road, Suite 225
San Antonio, Texas 78228-1110

James W. Augustin
Alexander H. Gillet
Carlos Guerrero, Jr.

Universal Energy Systems, Incorporated
4401 Dayton-Xenia Road
Dayton, Ohio 45432-1894

April 1991

Final Technical Report for Period September 1986 – August 1990

Approved for public release; distribution is unlimited.

91-16674

LABORATORY

AIR FORCE SYSTEMS COMMAND
BROOKS AIR FORCE BASE, TEXAS 78235-5601

91 11 27 062

NOTICE

This report has been reviewed and is approved for publication.

THOMAS W. WATSON
Contract Monitor

WILLIAM E. ALLEY, Technical Director
Manpower and Personnel Division

HAROLD G. JENSEN, Colonel, USAF
Commander

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE
April 1991

3. REPORT TYPE AND DATES COVERED
Final Report – September 1986 – August 1990

4. TITLE AND SUBTITLE
Factor Analytic Examination of the Armed Services Vocational Aptitude Battery (ASVAB) and the Kit of Factor-Referenced Tests

5. FUNDING NUMBERS
C – F41689-87-D-0012
F41689-84-D-0002
PE – 63227F
PR – 2922, 7719
TA – 02, 18
WU – 02, 04

6. AUTHOR(S)
Werner Wothke
Linda T. Curran
James W. Augustin
Carlos Guerrero, Jr.
R. Darrell Bock
Benjamin A. Fairbank
Alexandar H. Gillet

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Operational Technologies Corporation
5825 Callaghan Road, Suite 225
San Antonio, Texas 78228-1110

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAMES(S) AND ADDRESS(ES)
Manpower and Personnel Division
Air Force Human Resources Laboratory
Brooks Air Force Base, Texas 78235-5601

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
AFHRL-TR-90-67

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

The Armed Services Vocational Aptitude Battery (ASVAB) is used to select and classify enlisted personnel. Although the factor structure of the ASVAB has been assessed and compared to similar aptitude tests, no thorough factor reference study has been done with the current ASVAB configuration. To examine the factor structure of the ASVAB, 46 tests from the Kit of Factor Referenced Cognitive Tests (the Kit) and the 10 ASVAB subtests were administered to a sample of airmen. Because 56 tests were investigated, it was impossible to have every examinee receive every test. Matrix sampling was used to pair each test with each of the other tests. After consideration of descriptive statistics and after editing, the data were assembled into a correlation matrix for exploratory and confirmatory factor analysis. Matrix sampling requires special factor analytic methods. The factor analyses indicated that the correlation structure among the ASVAB scores required three factors to explain, whereas that in the Kit scores required six. The factors used to explain the ASVAB can largely be placed within the factor space of the Kit factors, indicating that the abilities measured by the ASVAB are a subset of the abilities measured by the Kit. Future research to enhance selection and classification should focus on abilities not currently measured by the ASVAB.

14. SUBJECT TERMS
ASVAB
confirmatory factor analysis
construct validity
factor analysis
LISREL
selection
test construction

15. NUMBER OF PAGES
76

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev 2-89)
Prescribed by ANSI Std. Z39-18
298-102

SUMMARY

The Armed Services Vocational Aptitude Battery (ASVAB) is used for selection and job classification of enlisted personnel by the Armed Services. The factor structure of the ASVAB, in its current composition, has never been examined in reference to a known cognitive battery. To determine the factor structure of the ASVAB, tests from the Kit of Factor-Referenced Cognitive Tests (the Kit) were administered along with the 10 subtests on the ASVAB. The Kit was developed by the Educational Testing Service and consists of 72 tests that measure 23 aptitude factors. Two tests per aptitude factor were selected based upon the test administration time, ease of administration, and ease of scoring. A set of 56 cognitive ability tests, 46 of which were chosen from the Kit and 10 of which were the ASVAB subtests, was administered to a sample of Air Force reservists and basic trainees. Because of the large number of tests involved, a matrix sampling scheme was used in order that each test might be paired with each other test. The resulting data were edited and assembled into a correlation matrix which presented the intercorrelations of all 56 tests. The data were factor analyzed to determine the joint factor structure of the two test batteries. Three factors accounted for the correlation structure in the ASVAB. Six factors accounted for the correlations among the factor-referenced tests. The simultaneous analysis of the two batteries showed that most of the factor space for the ASVAB fits within the factor space of the Factor-Referenced Cognitive Tests.

PREFACE

This report documents the efforts conducted under two projects. One project was completed as part of the Armed Services Vocational Aptitude Battery (ASVAB) Factor Reference Study-Data Collection (Task 47 under Contract F41689-84-D-0002). The other project was completed as part of the Factor Reference Study-Data Analysis (Task 05 under Contract F41689-87-D-0012). These contracts are documented under Air Force Human Resources Laboratory (AFHRL) Work Units 77191840 and 29220202, respectively. These projects represent the continuing effort of the AFHRL to fulfill its research and development (R&D) responsibilities by examining the factor structure of the ASVAB in comparison to a known factor-referenced aptitude battery, the kit of Factor-Referenced Cognitive Tests developed by the Educational Testing Service.

Special appreciation is expressed to Dr. Malcolm James Ree, Air Force Human Resources Laboratory, for originating and designing this research and for providing technical guidance once the project was under way.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

Page

TABLE OF CONTENTS (Concluded)

LIST OF FIGURES

LIST OF TABLES

FACTOR ANALYTIC EXAMINATION OF THE ARMED SERVICES VOCATIONAL APTITUDE BATTERY (ASVAB) AND THE FACTOR REFERENCE TEST

I. INTRODUCTION

The present study addresses the construct validity of the ASVAB. The construct validity of a test battery denotes the extent to which the battery measures the traits, abilities, or theoretical constructs which it was designed to measure. Construct validity is thus the most general or inclusive term for validity, but general usage restricts construct validity to exclude face validity and predictive validity. The construct validity of a test can be measured in various ways, most obviously by determining whether scores obtained by examinees taking the test battery correlate well with other measures of the same abilities or constructs. It is also possible to investigate construct validity through other, more statistically intensive techniques. The most frequently used of these techniques is factor analysis, which allows one to determine the factor structure underlying the various components or tests which comprise a test battery. One can also examine the relationship of the obtained factors to the factor structure of other test batteries which are known to measure the constructs. This study assesses the construct validity of the ASVAB through a joint factor analysis of the ASVAB subtests and a subset of the tests which make up the Kit of Factor-Referenced Cognitive Tests (Ekstrom, French, Harman, with Derman, 1976a).

Past studies of the factor structure of the ASVAB, such as that performed by Ree, Mullins, Mathews, and Massey (1982), are summarized by Curran, Kucinkas, and Welsh (1990). These studies have shown that four moderately intercorrelated factors generally emerge from factor analyses of the 10 subtests: a verbal factor, a quantitative factor, a speeded factor, and a factor which corresponds to technical knowledge. These factors have tended to emerge across all forms of the ASVAB since its present subtest structure was established with Forms 8, 9, and 10. The intercorrelations of the factors have been attributed to the influence of a general cognitive ability (GCA) factor in the various subtests (Welsh et al., 1990).

Comparisons of the ASVAB with other cognitive batteries have included an investigation by Hunter, Crosson, and Friedman (1985) which studied the ASVAB in relation to the General Aptitude Test Battery (GATB). Among other findings, Hunter et al., (1985) concluded that the ASVAB is a better measure of GCA than is the GATB, but that the two batteries measure much of the same ability structure. A later, smaller scale investigation (Palmer, Haywood, Fairbank, & Earles, 1990) showed that the GATB and the ASVAB share considerable variance, probably attributable to GCA, but that the ASVAB has subtests which measure a technical knowledge domain that the GATB does not measure, and the GATB measures spatial abilities not measured by the ASVAB. Welsh et al. (1990) report other comparisons of the ASVAB with tests of reading ability, but aside from the work of Hunter et al. (1985), there has been no recent extensive comparison of the ASVAB with another test battery.

The present research is intended to address the need for a construct validation of the ASVAB by means of comparing it with another complex test battery. A comparison with such a battery might yield insights on questions of theoretical import and contribute to the resolution of practical issues regarding the actual and ideal composition of the ASVAB. For this purpose, subtests from the Kit of Factor-Referenced Cognitive Tests (Ekstrom et al., 1976a), hereafter called the Kit, published by the Educational Testing Service (ETS) were analyzed with the ASVAB.

II. METHODOLOGY

Phase I: Development of Methodology

Measures

Armed Services Vocational Aptitude Battery (ASVAB). The ASVAB is the test battery which the United States Military Services have used since 1976 to determine the cognitive qualification of applicants for service. The battery serves both to determine whether applicants meet minimum enlistment standards and to aid in determining the specialty area in which an applicant might most benefit from advanced training. The ASVAB contains ten subtests, two of which, Coding Speed and Numerical Operations, are speeded tests, and eight of which are power tests. The power subtests are Word Knowledge, Paragraph Comprehension, General Science, Mathematics Knowledge, Arithmetic Reasoning, Electronics Information, Auto and Shop Information, and Mechanical Comprehension. The total battery, which includes 344 questions, requires 144 minutes of testing time; however, the administration time, which includes not only testing time but also time between tests and time for the reading of instructions, is somewhat longer.

The Kit. The Kit is based upon the scientific literature concerning cognitive aptitude factors. The Kit contains 72 cognitive tests designed to measure 23 different aptitude factors. Three or more tests are provided for each of 21 factors, and two tests are provided for each of the remaining two factors. The authors of the Kit recommend that more than one test be used to identify a particular factor.

Two tests for each factor represented in the Kit were selected for study, for a total of 46 tests from the group of 72. For this study, the most desirable tests were those which were shorter in required administration time, easier to answer correctly, easier to administer, and easier to score, and which had an answer key. Because of testing time constraints (a maximum of 3.5 hours was available for testing), required administration time was a heavily weighted criterion for test selection. The information presented in Table 1 was compiled for use in selecting the tests. The table also notes the 46 factor-referenced tests that were selected.

Test Booklet Construction

Eight test booklets were constructed for the study. Two of these booklets contained the 10 ASVAB subtests. Table 2 presents the assignment of ASVAB subtests to Factor-Referenced Test Booklets 1 and 2. The order of the subtests was the same as their order in the operational ASVAB. Form 13c of the ASVAB was used in the study, but all information identifying the tests as ASVAB subtests was removed prior to reproducing the booklets. Form 13c is identical to Form 8a, the normative standard, and has the same subtest composition and factor structure as those found in current operational forms.

Booklets 3 through 8 consisted of tests which were selected from the Kit. The tests were assigned to booklets to distribute the time requirements evenly. No tests representing the same factor were allowed in the same booklet. Time requirements for the booklets ranged from 66 to 68 minutes.

Difficulty scores assigned to each test were obtained by summing the estimates of the low educational grade level and high educational grade level for which the test is suitable. Low and high grade estimates reported in the Kit were used. The difficulty scores for individual tests ranged from 18 to 27. Based on the preliminary assignment of tests to booklets, average difficulty measures were determined for each booklet. This measure was obtained by summing the difficulty estimates for the individual tests assigned to a booklet and dividing the total by the number of tests assigned to the booklet. The range of average difficulty levels among the six booklets was 1.89. To reduce this range and to better balance the average difficulties, tests within the same time limits were exchanged among

Table 1. Factor-Referenced Cognitive Tests

Factor symbol and name	#	Test name	Suitable levels Low	Suitable levels High	Time	Score prob	Select	Comment
CF Closure, Flexibility	1	Hidden Figures	8	16	24	---	---	
	2	Hidden Patterns	6	16	6	---	Yes	E, S
	3	Copying	6	16	6	Yes	Yes	E
CS Closure, Speed of	1	Gestalt Completion	6	16	4	---	Yes	2
	2	Concealed Words	6	16	8	---	Yes	2
	3	Snowy Pictures	6	16	6	---	---	
CV Closure, Verbal	1	Scrambled Words	8	16	10	---	Yes	3
	2	Hidden Words	8	16	8	Yes	---	
	3	Incomplete Words	8	16	6	---	Yes	3
FA Fluency, Associational	1	Controlled Associations	6	16	12	---	Yes	E, M
	2	Opposites	6	16	10	---	Yes	E, M
	3	Figures of Speech	9	16	10	Yes	---	
FE Fluency, Expressional	1	Making Sentences	6	16	10	---	Yes	K
	2	Arranging Words	6	16	10	Yes	Yes	K
	3	Rewriting	6	16	10	Yes	---	
FF Fluency, Figural	1	Ornamentation	6	16	4	---	Yes	E, S
	2	Elaboration	6	16	4	---	Yes	E, S
	3	Symbols	9	16	10	Yes	---	
FI Fluency, Ideational	1	Topics	8	16	8	---	Yes	M
	2	Theme	8	16	8	Yes	---	
	3	Thing Categories	8	16	6	---	Yes	M
FW Fluency, Word	1	Word Endings	6	16	6	---	Yes	
	2	Word Beginnings	6	16	6	---	Yes	
	3	Word Beginnings & Endings	6	16	6	---	---	
I Induction	1	Letter Sets	8	16	14	---	Yes	4
	2	Locations	8	16	12	---	---	
	3	Figure Classification	8	16	16	---	Yes	4
IP Integrative Process	1	Calendar	8	16	14	---	Yes	
	2	Following Directions	9	16	14	---	Yes	
MA Memory, Associative	1	Picture-Number	6	16	14	---	Yes	4
	2	Object-Number	6	16	10	---	Yes	4
	3	First & Last Names	6	16	10	---	---	
MS Memory Span	1	Auditory Number Span	6	16	10	---	Yes	A
	2	Visual Number Span	6	16	10	---	---	
	3	Auditory Letter Span	6	16	10	---	Yes	A

Table 1. (Continued)

Factor symbol and name	#	Test name	Suitable levels Low	High	Time	Score prob	Select	Comment
MV Memory, Visual	1	Shape Memory	6	16	16	Yes	---	
	2	Building Memory	6	16	16	---	Yes	
	3	Map Memory	6	16	12	Yes	Yes	S
N Number	1	Addition	6	16	4	---	Yes	4
	2	Division	6	16	4	---	---	
	3	Sub & Multiplication	6	16	4	---	Yes	4
	4	Add & Subtraction Correction	6	16	4	---	---	1
P Perceptual Speed	1	Finding A's	6	16	4	---	Yes	4
	2	Number Comparison	6	16	3	---	Yes	4
	3	Identical Pictures	6	16	3	---	---	
RG Reasoning, General	1	A. thmetic Aptitude	6	12	20	---	Yes	E
	2	Math Aptitude	11	16	20	---	---	
	3	Necessary Arithmetic Operations	6	16	10	---	Yes	E, S
RL Reasoning, Logical	1	Nonsense Syllogisms	11	16	8	---	Yes	S
	2	Diagramming Relationships	9	16	8	---	Yes	S
	3	Inference	11	16	12	---	---	
	4	Deciphering Languages	11	16	16	---	---	
S Spatial Orientation	1	Card Rotations	8	16	6	---	Yes	
	2	Cube Comparisons	8	16	6	---	Yes	
SS Spatial Scanning	1	Maze Tracing Speed	6	16	6	Yes	Yes	E, S
	2	Choosing A Path	8	16	14	---	---	
	3	Map Planning	6	16	6	---	Yes	E, S
V Verbal Comprehension	1	Vocabulary I	7	12	8	---	Yes	E, S
	2	Vocabulary II	7	12	8	---	Yes	E, S
	3	Extended Range Vocabulary	7	16	12	---	---	
	4	Advanced Vocabulary I	11	16	8	---	---	
	5	Advanced Vocabulary II	11	16	8	---	---	
VZ Visualization	1	Form Board	9	16	16	Yes	---	
	2	Paper Folding	9	16	6	---	Yes	S
	3	Surface Development	9	16	12	---	Yes	S
XF Flexibility, Figural	1	Toothpicks	11	16	12	Yes	Yes	4
	2	Planning Patterns	10	16	4	---	---	
	3	Storage	10	16	6	---	Yes	4

Table 1. (Concluded)

Factor symbol and name	#	Test name	Suitable levels Low	High	Time	Score prob	Select	Comment
XU Flexibility of Use	1	Combining Objects	9	16	10	---	Yes	M
	2	Substitute Uses	9	16	10	Yes	---	
	3	Making Groups	9	16	10	---	Yes	M
	4	Different Uses	6	16	10	Yes	---	

Comments:
E = Easier test
S = Shorter administration time
A = Easier to administer
M = Easier to score
K = Key available
1 = Too much guessing in N4
2 = Snowy pictures too dependent on printing quality
3 = Hidden words too similar to popular puzzle
4 = Selected by AFHRL

Table 2. Assignment of ASVAB Subtests to Booklets

Factor-Referenced test booklet 1: ASVAB subtest	Time	Factor-Referenced test booklet 2: ASVAB subtest	Time
General Science (GS)	11	Numerical Operations (NO)	3
Arithmetic Reasoning (AR)	36	Coding Speed (CS)	7
Word Knowledge (WK)	11	Auto/Shop Information (AS)	11
Paragraph Comprehension (PC)	13	Mathematics Knowledge (MK)	24
		Mechanical Comprehension (MC)	19
		Electronics Information (EI)	9
Total (minutes)	71	Total (minutes)	73

booklets, while observing the restriction that no two tests representing the same factor be allowed in the same booklet. As a result of this final assignment of tests to booklets, the range of difficulties was reduced to .02. The average difficulties of Booklets 3 and 4 were 22.86; average difficulties for Booklets 5 through 8 were all slightly higher at 22.88.

Information concerning the composition of factor-referenced test Booklets 3 through 8 is presented in Table 3. Tests within each booklet were ordered from least difficult at the front of the booklet to most difficult at the back. When two or more tests had the same difficulty level, tests were ordered by time requirement, from shortest to longest.

Table 3. Composition, Times, and Difficulties of Factor Booklets

Factor-Referenced Test Booklets																	
3			4			5			6			7			8		
Test	Tm	Df	Test	Tm	Df	Test	TM	Df	Test	Tm	Df	Test	Tm	Df	Test	Tm	Df
RG1	20	18	V2	8	19	P1	4	22	V1	8	19	N3	4	22	FF2	4	22
N1	4	22	RG3	10	22	SS3	6	22	P2	3	22	CS1	4	22	CF3	6	22
FA2	10	22	MA1	14	22	FW1	6	22	FF1	4	22	CF2	6	22	SS1	6	22
MS1	10	22	S2	6	24	FF1	10	22	FW2	6	22	FE2	10	22	CS2	8	22
CV3	6	24	FI1	8	24	MA2	10	22	S1	6	24	MV3	12	22	MS3	10	22
XU3	10	25	I1	14	24	MV2	16	22	I3	16	24	FI3	6	24	FA1	12	22
RL1	8	27	VZ2	6	25	RL2	8	25	XU1	10	25	IP1	14	24	CV1	10	24
						XF3	6	26	IP2	14	25	VZ3	12	25	XF1	12	27
	68			66			66			67			68			68	
Average Difficulties:																	
22.86			22.86			22.88			22.88			22.88			22.88		

Note. See Table 1 for the key to factor symbols and test numbers. Times (Tm) are reported in minutes. Difficulty levels (Df) are the sums of low and high educational grade level estimates.

The ASVAB subtests in Booklets 1 and 2 were printed on 50# white offset to duplicate the appearance of the ASVAB Form 13c. The factor-referenced tests in Booklets 3 through 8 were reproduced with permission from ETS. They were printed on 70# white vellum offset paper to achieve a high degree of opacity. This was particularly important for the reproduction of memory tests and tests involving illustrations, such as the Gestalt

Completion Test and the Concealed Words Test. Each of the eight booklets was stamped with a unique control number for use in monitoring the location and status of booklets during the study.

Prior to reproduction, small changes were made to the example test items in the instructions of two factor-referenced tests. The changes were made after personal communication with Dr. Ruth Ekstrom, Senior Research Scientist at ETS and an author of the Kit. In the example items given for the Making Groups Test (XU-3), items to be grouped were changed to single spacing to resemble item lists for the actual test questions. The double spacing of the example list on the test copy originally received from ETS was regarded as confusing and inconsistent with the format in which items were listed in Part 1 and Part 2 of the test. On the instruction page for the Storage Test (XF-3), dashed lines were added to the faces of the three containers presented as examples, to make their appearance consistent with the appearance of the containers in the test.

On the front cover of each copy of Booklets 3 through 8 was space for the examinee's name, social security number, date of birth, and testing date. Gender, service, education level, and population group were also indicated by each recruit. The back covers of Booklets 3 through 8 contained a series of spaces where test scorers could record scores for the tests within each booklet. Consequently, Booklets 3 through 8 could be used only once. Booklets 1 and 2 were reusable in that each recruit recorded descriptive information and test responses on a separate standard ASVAB answer sheet.

Test Administration Configuration

Plans were developed to administer two booklets to each examinee in a matrix sampling plan. Booklets were paired in all possible combinations so that each booklet was administered with each other booklet. It was desired to have an administration of the ASVAB both at the beginning and end of data collection so that the effect of time of year upon test performance could be examined. Consequently, two additional pairings were made. An administration of the complete ASVAB Form 13c was planned for the first and last testing sessions. This resulted in 30 pairings, as shown in Table 4.

Testing Sessions and Examinees

Each pair of booklets was to be administered to at least 200 examinees, with 15% oversampling. That is, each of 30 pairs was to be administered to 230 examinees, for a total of 6,900 examinees. As explained below, data from some of the examinees were

Table 4. Test Booklet Pairings

Pair	Test 1	Test 2	Pair	Test 1	Test 2
1	Operational ASVAB		16	Factor 7	Factor 1
2	Factor 2	Factor 3	17	Factor 8	Factor 3
3	Factor 3	Factor 4	18	Factor 1	Factor 4
4	Factor 4	Factor 5	19	Factor 2	Factor 5
5	Factor 5	Factor 6	20	Factor 3	Factor 6
6	Factor 6	Factor 7	21	Factor 4	Factor 7
7	Factor 7	Factor 8	22	Factor 5	Factor 8
8	Factor 8	Factor 2	23	Factor 6	Factor 1
9	Factor 1	Factor 3	24	Factor 7	Factor 2
10	Factor 4	Factor 2	25	Factor 8	Factor 4
11	Factor 3	Factor 5	26	Factor 1	Factor 5
12	Factor 4	Factor 6	27	Factor 2	Factor 6
13	Factor 5	Factor 7	28	Factor 3	Factor 7
14	Factor 6	Factor 8	29	Factor 8	Factor 1
15	Factor 1	Factor 2	30	Operational ASVAB	

unusable; thus, the final sample size was smaller than 6,900. Of the 230 examinees for each pair, 191 were to be male and 39 were to be female, consistent with gender proportions of Air Force recruits (83.1% males and 16.9% females). The examinees were Air Force enlistees in their eleventh day of basic training. Table 5 shows the demographic characteristics of the sample. Most (83%) were male, white (86%) and high school graduates. All had been selected for enlistment using the ASVAB. Of the total 6,751 cases, 16.9% of the recruits were female and 13.3% were Afro-American. These two classifications are not statistically independent: One out of four Black recruits is female as compared to White (and other) recruits, where approximately one of six is female.

Manuals for Test Administration

Separate test administration manuals were prepared for the eight different test booklets. The content of each manual was organized into two sections. The first section presented general information on the study design and specific instructions concerning testing conditions and standards, security, distribution of testing materials, and maintenance of records such as inventory sheets and logs of testing sessions.

The second section contained specific test administration directions for the factor-referenced tests within each booklet. The manuals for Booklets 1 and 2, containing the ASVAB subtests, incorporated the instructions from the standard ASVAB Manual for

Table 5. Joint Distribution of Ethnic Group, Gender, and Education Level

		Education			
		≤ 12 years	HS or GED	Some College	Subtotal
Group: Afro-American					
Male	N	22.00	420.00	231.00	673
	row %	3.27	62.41	34.32	
Female	N	2.00	126.00	96.00	224
	row %	0.89	56.25	42.86	
Subtotal	N	24.00	546.00	327.00	897
	row %	2.68	60.87	36.45	
Group: White, Indian, Asian, Hispanic and "Other"					
Male	N	115.00	3685.00	1137.00	4937
	row %	2.33	74.64	23.03	
Female	N	8.00	663.00	246.00	917
	row %	0.87	72.30	26.83	
Subtotal	N	123.00	4348.00	1383.00	5854
	row %	2.10	74.27	23.62	

Administration (DOD 1304.12A, October 1983). No administration manuals were available from ETS for the factor-referenced tests in Booklets 3 through 8. Consequently, manuals were developed using the instructions which appear at the beginning of each ETS test. The manuals were written in a format similar to that of the ASVAB manual and included instructions to the test administrator, as well as test directions that were read verbatim to examinees.

Test Scoring Plans

Recruits answered the ASVAB questions in factor-referenced test Booklets 1 and 2 on standard machine-scannable answer sheets. Scanning and scoring of the ASVAB subtest data were performed by the Air Force Human Resources Laboratory (AFHRL).

The 46 factor-referenced tests were diverse in their formats and ranged from objective multiple-choice vocabulary tests to pattern copying and sentence writing tests which required careful inspection and considerable judgment by raters during scoring. The Manual for Kit of Factor-Referenced Cognitive Tests (Ekstrom et al., 1976b) provides information on scoring many of the tests. For some tests, answer keys are provided; for others, preparation of an answer key or set of scoring procedures is left entirely to the test user. Instructions and keys in the Kit Manual were fully incorporated into a more detailed and extensive set of procedures and examples prepared for this study.

Special scoring manuals were developed for factor-referenced test Booklets 3 through 8. The manuals were required because all the tests in these booklets would be hand-scored. This was due to the fact that recruits answered both objective and open-ended test questions by writing directly in the consumable booklets.

The scoring manuals for the factor-referenced test booklets all contained two sections. Section one was the same in each manual and presented general guidelines for scoring. Among the topics addressed were rater independence, scoring marks and notations, use of templates, spelling, and corrections for guessing.

The second section was unique to each manual, as it contained step-by-step instructions for scoring each of the seven or eight tests within a specific booklet. For many objective tests, answer keys were provided with the instructions. For other objective tests, particularly those with unnumbered items, templates which could be placed over the test pages were constructed for scoring. The step-by-step scoring instructions for tests that called for open-ended responses were the most detailed and were accompanied by example pages of simulated responses with comments on how the responses should be scored. Tables to be used in arriving at corrected scores when the score was the number of correct answers minus a fraction of incorrectly attempted items were also contained in the manuals.

Although instructions on the Surface Development Test (VZ-3) and the Figure Classification Test (I-3) indicate a correction for guessing, these tests were scored by simply counting the number of correctly answered items. In a personal communication, Dr. Ruth Ekstrom recommended that a "number correct" score be used due to the varying number of response alternatives for items within each of the two tests.

Phase II: Data Collection and Scoring

Selection of Test Administrators

Data collection required four test administrators at Lackland AFB, Texas, to ensure that standard testing procedures were followed, the testing schedule was met, and the project could efficiently test all recruits available for testing at any point in time. The staff of four test administrators was required to monitor large testing sessions (up to 100 examinees) and ensure completion of the specified tests within the narrow time limits (3-1/2 hours maximum) set aside for each test session. Another justification for additional test administrators was that it would allow the simultaneous testing, in different locations, of two or three groups with different pairs of booklets. Candidates for the test administrator position were required to have good verbal skills, including a clear voice and a high level of text reading accuracy and fluency. Some experience in public speaking, psychology, and testing was preferred.

Training of Test Administrators

Due to the complexity of the study design and the diversity of the factor-referenced tests, all four test administrators were required to attend a 2-day training session. The test administration team practiced with each of the test administration manuals in order to gain proficiency with the unique instructions for each test. Special emphasis was placed on mastering the administration of the Memory Span (MS-1 and MS-3) tests. These particular tests require the test administrator to read strings of digits or letters at 1-second intervals. The administrators also staged mock question-and-answer sessions to anticipate queries that might arise during the actual testing session.

The testing team was also briefed on procedures for assuming responsibility for the test subjects from their Training Instructor (T.I.). These procedures included asking the T.I. if any recruit had previously taken the tests, if there were any medical appointments, or if there were any other appointments that would interfere with completion of the testing session. The T.I. must then be told what time to return for his flight.

The temporal aspects of test administration were also addressed during training. This included a discussion of the tentative schedule for administering booklet pairs, and steps that needed to be taken to ensure each testing session was completed within the allotted time. Of particular concern were the narrow time constraints involved in actual test administration. The administration time required for most pairs of booklets, together with a short break between booklets, approached the maximum time available for any one session. Because of these time limits, efficient administration and careful proctoring during the testing sessions were required.

Instructions concerning the secure storage of the completed test booklets were provided during training. Finally, procedures concerning distribution and collection of the testing materials were discussed.

Pilot Administration of Factor-Referenced Test Booklets

Two pilot sessions were conducted at Lackland AFB: (a) to provide administrators the opportunity to practice reading the test directions, (b) to identify potential procedural problems, and (c) to check on the clarity of the instructions.

In the first session, 41 male recruits were assembled to read through the directions of all tests in Booklets 3, 4, and 5, and to complete the descriptive and demographic items on a booklet cover. The recruits studied actual test items. Then they were asked about problems with understanding the directions, about suggestions to improve the directions, and if they understood how to record answers. The procedure was repeated for all the tests.

The success of the pilot administration of the Auditory Number Span Test (MS-1) confirmed a decision to have test administrators read the items in the Auditory Number Span Test and the Auditory Letter Span Test (MS-3) instead of having the items recorded on audio tape for playback during test administration.

Two of the tests, Map Planning (SS-3) from Booklet 5 and Making Groups (XU-3) from Booklet 3, required more detailed instructions because the test subjects indicated some difficulty in understanding them. Additional paragraphs explaining the examples were written for Tests SS-3 and XU-3 and added to the instructions in the administration manuals.

During the second session, 13 females were read the directions for all tests in Booklets 6, 7, and 8. The same review procedures used in the first pilot session were followed. Recruits completed a booklet cover and Part I of six tests with complex directions: Figure Classification (I-3), Arranging Words (FE-2), Auditory Letter Span (MS-3), Surface Development (VZ-3), Combining Objects (XU-1), and Storage (XF-3). These six tests were viewed to be a potential source of problems; however, no problems occurred with them. The recruits also completed Part I of Tests SS-3 (Booklet 5) and XU-3 (Booklet 3) as part of the pilot testing of the new directions. The elaboration of directions was effective enough to compensate for earlier misunderstandings.

Data Collection

Data collection began with the administration of ASVAB Form 13c and then the first pair of factor-referenced test Booklets 2 and 3. A complete list of factor booklet pairings and their administration dates appear in Table 6. Some pairings took longer to complete than others. To take full advantage of the flow of individuals passing through the testing facility, both recruits and reservists were tested.

Table 6. Booklet Pairings and Administation Dates

Pair	Test 1	Test 2	Administration Dates
1	Operational ASVAB		03 April - 10 April
2	Factor 2	Factor 3	09 April - 16 April
3	Factor 3	Factor 4	13 April - 20 April
4	Factor 4	Factor 5	17 April - 20 April
5	Factor 5	Factor 6	22 April - 28 April
6	Factor 6	Factor 7	28 April - 06 May
7	Factor 7	Factor 8	29 April - 12 May
8	Factor 8	Factor 2	06 May - 14 May
9	Factor 1	Factor 3	14 May - 21 May
10	Factor 4	Factor 2	18 May - 21 May
11	Factor 3	Factor 5	20 May - 04 June
12	Factor 4	Factor 6	26 May - 16 June
13	Factor 5	Factor 7	29 May - 04 June
14	Factor 6	Factor 8	03 June - 23 June
15	Factor 1	Factor 2	16 June - 30 June
16	Factor 7	Factor 1	05 June - 18 June
17	Factor 8	Factor 3	10 June - 25 June
18	Factor 1	Factor 4	12 June - 23 June
19	Factor 2	Factor 5	17 June - 25 June
20	Factor 3	Factor 6	19 June - 01 July
21	Factor 4	Factor 7	24 June - 01 July
22	Factor 5	Factor 8	26 June - 08 July
23	Factor 6	Factor 1	01 July - 07 July
24	Factor 7	Factor 2	05 July - 10 July
25	Factor 8	Factor 4	09 July - 15 July
26	Factor 1	Factor 5	10 July - 21 July
27	Factor 2	Factor 6	14 July - 21 July
28	Factor 3	Factor 7	16 July - 24 July
29	Factor 8	Factor 1	21 July - 29 July
30	Operational ASVAB		02 Sept - 09 Sept

The main testing room at the AFHRL Lackland AFB facility, with a capacity of over 100 subjects, served as the principal data collection site. Two additional rooms located in different buildings were used as supplementary data collection sites whenever the pairing schedule and the number of recruits required their use. Each of these rooms had a capacity of approximately 30 recruits.

At each test session, one administrator read all directions for all tests in the designated booklets. Unless occupied with simultaneous administration to another group in a supplemental room, the other test administrators served as proctors during the session.

Makeup test sessions were held to obtain replacements for incomplete factor booklets which were attributable to group administration problems or individual illness. In one pair 13 session, 60 recruits were evacuated from the main testing room when a faulty fire alarm went off. Upon return to the room, inadequate time remained to complete Booklets 5 and 7. On three separate occasions, Booklet 4 was not completely administered. On two of these occasions, Booklet 4 was paired with Booklet 3; it was paired with Booklet 5 on the third.

During several test sessions, some recruits became too ill to continue and were replaced. One administration problem that spanned several test sessions involved the Finding A's Test (P-1) in Booklet 5. Each of the two test parts in P-1 has four pages of items which are very similar in appearance. The numbered test parts are poorly marked. During several initial test sessions, some recruits mistook the third and fourth pages of Part 1 for the first two pages of Part 2 when they were instructed to proceed to Part 2. Consequently, they spent twice the designated time on Part 1 and left Part 2 unattempted. The combination of an announcement during test administration of the correct page numbers for each part and very close monitoring by the proctors virtually eliminated this problem from subsequent sessions. Booklets from pairings 4 and 5 with no response to Part 2 of the Finding A's Test were replaced as were the appropriate paired booklets.

Selection and Training of Test Scorers

Test scorers were chosen using the following selection criteria: (a) completion of at least 2 years of college, including course work in English/Composition; (b) possession of excellent reading and grammatical skills; (c) good attention to detail; and (d) some background in education, psychology, or testing (preferred, but not required).

Each individual was assigned to score two booklets; one booklet would become too tedious, whereas more than two would reduce accuracy, expertise, and speed. At least 16 booklets could be accurately scored during an 8-hour day after a period of training. Accuracy and good judgment were always stressed as being of greater importance than speed.

Fifteen individuals were initially hired, but five scorers left. They were replaced and supplemented with two additional scorers. Of the 22 scorers who worked on the project, six were enrolled in undergraduate programs, eight had recently earned bachelor's degrees, and eight were enrolled in graduate school.

Each initial team of five scorers was trained to an acceptable level of proficiency on one booklet. Repeating the training process, the team was then trained to score the second booklet. Test scorers worked independently while scoring valid test booklets. Scorers used plastic overlays and grease pencils so that no scoring marks would be made directly on the booklet pages, thereby ensuring that the ratings and scores given by each scorer would be independent of the ratings and scores given by other scorers.

Distribution of Booklets to Scorers

The 75 numerically sequenced factor-referenced booklets were sorted into five sets of 15 booklets. Each set was randomly assigned such that all raters served as first, second, and third scorer for approximately 1/3 of the booklets. The booklets were assigned to avoid having one scorer follow another on a regular basis, but some adjustments were required for individual differences in scoring speed, illnesses, and turnover of personnel.

Quality Control

To ensure the quality of the scorers' ratings, test booklets were examined for two types of scorer problems: (a) differences among scorer ratings on tests considered to have only one correct score (i.e., tests which possessed a complete answer key), and (b) large differences among the scorer ratings on tests with open-ended questions that required substantial scorer judgment. Scored test booklets with either of these two problems were returned to their scorers for further inspection and possible rescoring.

Interrater Agreement

The factor-referenced tests can be placed in three general categories of ease/difficulty of obtaining interrater agreement. Category 1 includes tests for which a very high level of scorer agreement is easily attained. Tests in this category have a comprehensive answer key for scoring objective test items. Responses to test items are usually in the form of circles around or X's on the responses chosen as correct. A few of these tests involve writing letters or words. Only occasional interpretation of trainees' answer marks or handwriting is required.

Category 2 encompasses tests which possess noncomprehensive answer keys for test items. Some items have more than one correct answer, and new solutions or acceptable answers, beyond those provided by ETS, were found during scoring. These tests often require handwriting which must be deciphered by the scorer. Agreement among scorers can be slightly more difficult to attain for tests in this category; however, the interrater reliabilities are still quite high.

No answer keys are available for tests in Category 3, due to the open-ended nature of the test items. Only a set of guidelines and examples were provided to scorers. Substantial scorer judgment is required and deciphering of handwriting is often necessary. Consequently, differences among the three scorers can be more frequent and of greater magnitude for tests in Category 3 than for Category 1. Nevertheless, interrater reliabilities for these tests are also very high. All of the factor-referenced tests used in this study are listed by category in Appendix A.

Supplemental Procedures

As the scoring process advanced, supplemental procedures and answer key additions were incorporated into the scoring manuals. Changes were also recorded on the master copy of that manual, to ensure that new copies of the manual would reflect the additions. Procedures of a general nature which emerged during scoring included the following: (a) Items with multiple answers marked were scored as incorrect; (b) ambiguous numbers or letters were compared with other writing in that individual's test to assist in deciphering whether the response was correct; (c) when answers were superimposed, the clearly darker or larger one was accepted and scored; and (d) when the trainee's answer was to be indicated by filling a box, any mark within, through, or around that box was accepted.

Data Entry

Booklets which revealed problems attributable to illness or administration errors were not scored or entered in the data file. All hand-entered test data were verified using one of two methods. Data for about half of the booklets were verified using a double-entry method. Each of two clerks entered data from the same booklets. Their sets of entries were compared by a computer program, and a list of discrepancies generated. Staff personnel referred back to the original test booklets when necessary to resolve differences.

The remaining half of the booklets were verified by comparing complete printouts of the entered data with the booklets themselves. Discrepancies were noted on the printouts and corrections were then made. This second method was as effective as the double-entry method, but more efficient because of the way personnel were used.

Phase III: Data Analysis

Data Editing and Descriptive Analyses

The data set was screened further for clerical or programming errors that would be easily detectable with simple statistical methods. Specifically, the data records were tested for non-numeric characters in numeric data fields, apparently shifted data fields, and data values outside their permitted range. Furthermore, the 57 univariate distributions and 1,596 bivariate scatterplots of the continuous variables in the study were examined for indications of outliers due to non-response or guessing and for distribution mixtures, all of which could have affected the correlational structure among the variables. These latter examinations were performed by visual inspection rather than analytical method, because no "true" distributional forms for the Kit reference tests were known.

The demographic variables for Ethnicity and Education Level were recoded so as to avoid problems of small sample sizes and to simplify further data analyses. Ethnic Group was coded (1) for Afro-American (as the most populous minority) and (0) for all other groups; Education level was coded (-1) for up to 12 years of schooling, (0) for High School diploma or General Equivalency Diploma (GED), and (1) for some college. The variable Gender was recoded into (1) female and (0) male.

A series of descriptive statistical analyses were performed on cleaned data files of ASVAB and factor-referenced test scores. Frequency distributions and percentages were computed for demographic variables, including Education level, Gender, and Ethnic group. Univariate histograms, univariate summary statistics and bivariate scatterplots were computed for all continuous variables including Age, the 10 ASVAB subscales and the 46 Kit reference tests. These tabulations were completed for the entire group of recruits who participated in the study. Interrater reliabilities based on intraclass correlations were calculated for all the hand-scored ETS tests.

Estimation of Correlation Matrix

Sample correlations based on pairwise complete data are more efficient estimates of the population correlations than are those based on listwise complete data. Pairwise correlations use the entire information of the observed measures and, if the missing data process is independent of the values of the missing and observed data, provide unbiased estimates of the population correlations.

Pairwise complete correlations are also the only methods available to estimate the entire 56 by 56 correlation matrix of the ASVAB and the Kit reference tests. It proved to be technically infeasible to estimate so large a matrix by the statistically more attractive method of maximum likelihood along the lines proposed by Allison (1987).

The pairwise sample sizes should vary considerably due to the blockwise matrix sample design. Sample sizes for correlation between tests on the same booklet are considerably larger than for pairs of tests from different booklets. Also, due to the fact that two entire presentations of the operational ASVAB were administered to separate groups of 230 examinees before and after the collection of the entire 28-group measurement design, the pairing of Booklets 1 and 2 was effectively oversampled by a factor of three. The demographic variables Age and Education were assessed from nearly all recruits, and all correlations involving these two variables are therefore based on large pairwise sample sizes.

Asymptotic Sampling Variance of Correlation Coefficients

Under normality assumptions, the asymptotic sampling variance of the correlation coefficient r at sample size N is

$$\mathrm{AVAR}(r) = \frac{(1 - \mathrm{rho}^2)^2}{N} \tag{1}$$

(Anderson, 1984, pp. 120-122; Kendall & Stuart, 1977, p. 250). The term rho describes the population correlation. For practical purposes, rho may be estimated by r.

The sampling variance is inversely proportional to the bivariate sample size and, for a given sample size N, diminishes as the absolute population correlation |rho| approaches unity (cf. Table 7). The associated standard error of the correlation coefficient may be used

Table 7. Exemplary Sampling Variances of the Correlation Coefficient and Standard Errors at N = 220

rho	AVAR(r)	s.e.(r)
0.0	0.004545	0.06742
0.3	0.003764	0.06135
0.5	0.002557	0.05056
0.7	0.001182	0.03438
0.9	0.000164	0.01281

to construct approximate confidence intervals: The typical correlation listed in Appendix B is 0.5 or less. At an assumed average sample size of 220, the associated 95% confidence intervals are in the vicinity of plus or minus 0.10.

The standard error of sample correlations also serves as a useful test criterion for the Root-Mean-Square-Residual (RMSR) fit statistic used by LISREL and other multivariate programs. In cases with fairly homogeneous correlation coefficients, a well-fitting factor model should yield an RMSR statistic close to the typical standard error of estimation. With the present sample, good RMSR values would range between 0.050 and 0.067 for Kit models and between 0.030 and 0.037 for ASVAB models. Larger RMSR statistics indicate some degree of model misfit; RMSR values closer to zero indicate model overfit.

Modeling of Correlation Coefficients for AFQT-1, AFQT-2, and VE Scales

The Armed Forces Qualification Test (AFQT) and Verbal (VE) composite scales are linear combinations of the ASVAB subtests, defined as

$$\text{AFQT-1} = AR + WK + PC + NO/2 \tag{2}$$

$$\text{AFQT-2} = AR + WK + PC + MK \tag{3}$$

$$VE = WK + PC. \tag{4}$$

Correlation coefficients between the AFQT scales and the Kit reference tests involve subtests from three different booklets. They cannot be computed directly because each examinee answered only two booklets. Assuming that the correlation structure of the ASVAB was not greatly affected by the matrix sampling design, the correlation structure of the derived AFQT and VE scales can be modeled as a bilinear form of the pairwise complete correlation matrix, pre- and post-multiplied by the diagonal matrix of univariate standard deviations. If the goal is to model the correlation matrix of 59 variables (the 56 individual tests, AFQT-1, AFQT-2, and VE), given a 56 x 56 matrix **M** of subtest variances and covariances, and **T** is a 59 x 56 matrix, the bilinear form is **T** x **M** x **T'**.

Factor Analysis

Loss Functions. Exploratory factor analyses are computed with four different loss functions (if the data permit):

1. Complex weights: Diagonally weighted least squares (DWLS) using the reciprocal of the sampling variances for correlations. The asymptotic sampling variance of a correlation coefficient is given in equation (1). This weight formula is simultaneously sensitive to the finite range of correlation coefficients and variation in bivariate sample size due to pairwise deletion. If the analyzed correlation matrix is positive definite, the parameter estimates are asymptotically equivalent to a multiple-group maximum likelihood solution adapted for a missing-data design (as outlined by Allison, 1987).

2. Simple weights: DWLS using the inverse of the bivariate sample size, ($1/n_{ij}$). Trivially, these simple weights are sensitive only to variation in sample size, not to the size of the correlation coefficient. A simply weighted DWLS solution for pairwise complete data is therefore equivalent to a multiple-group unweighted least squares solution adapted to an incomplete data structure.

3. Unweighted Least Squares (ULS): This is the simplest fit function. Every element of the correlation matrix contributes equally to the solution. ULS is certainly less efficient than maximum likelihood, and is often less efficient than DWLS. However, in many cases ULS solutions are found to be rather close to those obtained by the maximum likelihood method.

   An advantage of ULS is, aside from its simplicity, that the function minimizes the root-mean-square-residual (RMSR) statistic, defined as

$$\mathrm{RMSR} = \{ \underset{i \leq j}{\mathrm{SUM}} (s_{ij} - \hat{s}_{ij})^2 \}^{0.5} \tag{5}$$

   where sij is the sample covariance for variables i and j and $\hat{s}$ij is the covariance for i and j reproduced by the factor model. Other advantages of ULS are that it produces a slightly conservative G^2 fit statistic (defined below), and does not require the sample correlation matrix to be positive definite.

4. Maximum Likelihood ML. Advantageous properties of the well-known maximum likelihood method are its consistency and efficiency. It minimizes the fit function

$$G^2 = \log |(\mathbf{Sigma})| + \mathrm{trace}[\mathbf{S}\,(\mathbf{Sigma})^{-1}] - \log |\mathbf{S}| - p, \tag{6}$$

where **S** is the sample covariance matrix of order p, **Sigma** is the corresponding model covariance matrix, and the notations $|\mathbf{S}|$ and $|(\mathbf{Sigma})|$ symbolize the determinants of the corresponding matrices.

Under normality, ML produces consistent parameter estimates and asymptotic standard errors, as well as a G^2 fit statistic that follows the chi-square distribution. Recent work in several statistical laboratories has found the ML estimator to be robust against deviations from normality.

A critical requirement for ML is that the sample moment matrix has to be strictly positive definite. In case the sample moment matrix is indefinite, a ridge may be added to its diagonal in order to obtain some "ridged-ML" parameter estimates (Joreskog & Sorbom, 1989). However, because sampling characteristics of such estimates are largely unknown, neither the G^2 statistic nor the standard errors for parameter estimates have established interpretations.

Identification and Rotation. The unrotated factor solutions are computed with the LISREL 7 program (Joreskog & Sorbom, 1989). Rotational identification is assured by (a) restricting the k factors to be uncorrelated and (b) fixing a triangular pattern of $k(k-1)/2$ factor loadings at zero values (Anderson & Rubin, 1956). These initial unrotated factor solutions are rotated by Promax (Hendrickson & White, 1964) into an oblique simple structure solution. A power coefficient of 4.00 is used. The advantages of the use of Promax are that it produces stable results for simple structure, it does not constrain the solution to be orthogonal, and it is computationally efficient.

Confirmatory Factor Analysis

Restricted Factor Structure for the Kit Reference Tests. Any attempt to relate ASVAB subtests to the Kit factors must deal with the conceptual problem that the orientation of the indeterminacy is generally resolved by first extracting any one of the many equivalent factor solutions. One may then conveniently rotate this solution so as to satisfy simple structure, to approximate another known or hypothesized solution. In the preceding section, Identification and Rotation, for example, the Promax algorithm was applied to obtain simple-structured oblique factors. When using confirmatory analysis, on the other hand, factors are typically directly estimated to fit a specified pattern of loadings or to coincide with some other, well-established solution. As a fundamental principle in confirmatory analysis, the structure and orientation of the factors must be known beforehand.

Apart from the exploratory solutions obtained from the same data, this study cannot claim prior knowledge sufficient for strict confirmatory analyses. Yet, by modeling some fairly basic aspects of the measurement design, it was possible to further refine the Promax rotated solution. Due to the fact that only one sample was used for all analyses, the solutions in this section should more accurately be labeled as restricted, rather than as confirmatory, factor analyses.

Regression of the ASVAB Subtests onto the Major Kit Factors. A simple way of comparing the ASVAB subtests to the major Kit factors is to compute a multiple regression equation for each subtest. Depending on how the residual values of the ASVAB are treated, the entire model can either take the form of a restricted regression analysis with fallible predictors, or be a joint restricted factor analysis of the ASVAB and Kit tests. If the residual covariance matrix of the ASVAB subtests is diagonal, we have the case of restricted factor analysis; if the matrix is generally symmetric, the regression model applies.

Hierarchical Factor Model for the ASVAB Regressed onto the Major Kit Factors. Hierarchical factor analysis is understood here in the modern sense of higher-order or second-order factor analytic models (cf., Bollen, 1989; Joreskog & Sorbom, 1989). In the LISREL model, first- and second-order factor structures are specified in perfectly analogous ways, the only difference being that the factors defined by the first-order structure become indicators at the second-order level. The function of the higher-order factors is to describe the correlation structure of several oblique first-order factors.

Identification conditions for the second-order structure are also equivalent to those in first-order multiple factor analysis. Specifically, a second-order model with exactly three first-order factors and one second-order factor is only just-identified. In the presence of exogenous predictor variables, however, even such a small hierarchical model tends to be more restricted than the multiple factor model. This is demonstrated in Figure 1. In panel A of the figure, the correlation structure of three dependent factors, generically labeled as "V," "S," and "Q," is described by the higher-order factor "H" which, in turn, is dependent on three predictors. After fixing one beta parameter (shown in Panel A of Figure 1) at a non-zero value to ensure scale identification, a total of nine estimated parameters describe the structural equation system. In Panel B, however, where each of the three dependent factors is regressed onto each of the three predictors, a total of 12 parameters have to be estimated. By routing the regression through the single second-order factor, as shown in Panel A of Figure 1, proportionality constraints are introduced into the prediction equations, with the effect that the relative impact of the various predictors remains constant for each dependent variable. This aspect of the hierarchical factor model is closely related to the MIMIC (multiple indicator, multiple causes) model proposed by Hauser and Goldberger (1971).

Major ASVAB Factors Regressed onto the Major Kit Factors. The final model is similar to the one sketched in Panel B of Figure 1. The three major ASVAB factors are regressed directly onto the six major Kit factors.

III. RESULTS AND DISCUSSION

Editing and Description

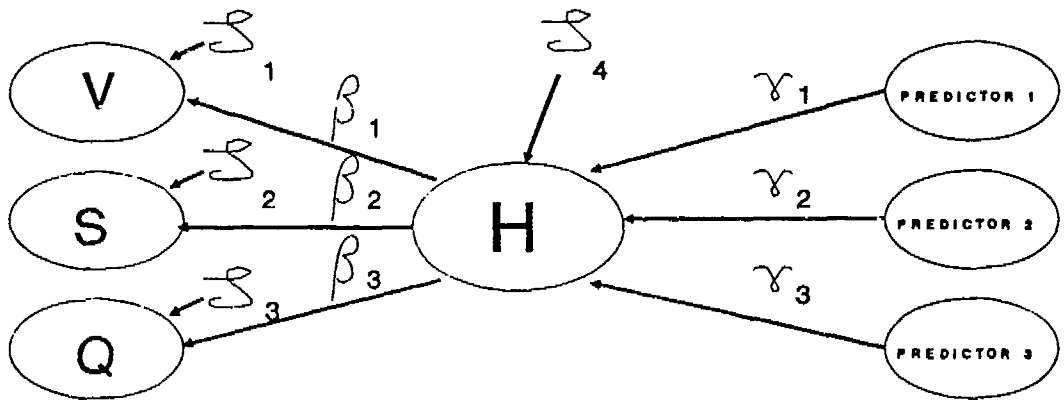
Data Editing

Cases with errors were either corrected or removed from the data set.

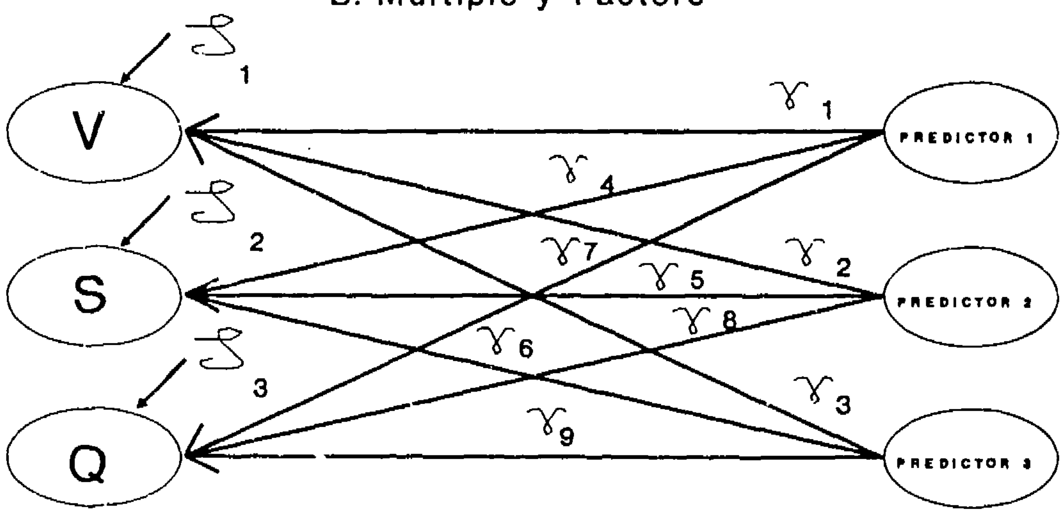
Descriptive Analysis

Care would be appropriate in generalizing the results of this research outside of the population from which the examinees were sampled (i.e., an Air Force population). The education level of the sample is below the national average figures reported by the Bureau of Census (1988). Whereas nationwide approximately 36% of the 25- to 29-year-old men and women in either ethnic group have attended at least some college, only 25% of the sample of recruits have done so. In the current sample, gender differences in education appear rather small and inconsequential for the White (and other) mainstream group, but there are striking differences in the Black subsample. Although, first of all, the college attendance figure for Black males (34.3%) is close to the national average, a larger proportion of Black females (42.9%) has obtained some college education. The higher educational mobility of young Black females has been previously documented (cf., Bock & Moore, 1986), yet we are not aware of specific aspects of the recruiting process that would selectively draw more

A: Hierarchical y-Factors



B: Multiple y-Factors



<u>Figure 1</u>. Linear Structural Relations

educated Black recruits into the Air Force and, at the same time, fail to attract the higher educated segments of the White (and other) mainstream. These stochastic dependencies in the demographic distribution pattern, taken together with the traditionally skewed distribution of the Genders in the Armed Services, do indicate a considerable degree of clumping in the total sample, which may disturb correlation structures and almost certainly adversely affect the tests of model fit.

Means, standard deviations, and skewness and kurtosis coefficients for the 57 continuous variables are given in Appendix B.

Interrater reliabilities for the hand-scored Kit tests ranged from .95 to .99. Though the reliabilities seem high, it should be noted that two-thirds of the hand-scored tests were objective tests with comprehensive answer keys and one accurate "correct" score.

Estimation of Correlation Matrix

Appendix B displays the pairwise complete correlation coefficients for Age, Education, Population Group, Gender, the 10 ASVAB subscales, and the 46 Kit reference tests.

Most correlation coefficients range between -0.2 and 0.5; the largest correlation in the matrix is 0.815 between AR (Arithmetic Reasoning, ASVAB) and RG1 (Arithmetic Aptitude Test, Kit). Due to the matrix sampling design, the bivariate sample size for individual correlations varies widely. For the Kit reference tests which were presented in Booklets 3 to 8, test scores located on different booklets were jointly observed on between 207 and 233 cases, while bivariate sample sizes for tests on the same booklet ranged between 1,533 and 1,594 (cf., Appendix C). The ASVAB subtests are presented in Booklets 1 and 2; corresponding bivariate sample sizes are 701 for subtests on different booklets, 2,055 and 2,057 for subtests located in the same booklet. Finally, identifying information on Education, Population Group, and Gender is available from all 6,751 respondents, and Age information from 6,015 cases. The bivariate sample sizes involving these four variables are similarly large.

Modeling of Correlation Coefficients for AFQT-1, AFQT-2, and VE Scales

The modeled correlation coefficients for the AFQT and VE scales appear in Appendix D. All three scales are highly correlated with each other, due to the sizable common vocabulary component defined by ASVAB subtests WK + PC. Those ASVAB and Kit subtests which involve reasoning, numeric, or spatial tasks correlate higher with the AFQT scales than with the VE scale. Both AFQT scales have correlation structures which are virtually identical to those of the Kit reference tests.

Factor Analyses

Exploratory Factor Analyses

ASVAB Subtests, Using Pairwise Complete Correlations. The first set of exploratory factor analyses were performed on the pairwise complete correlation matrix for the 10 ASVAB subtests. The fit statistics for up to five factors are given in Table 8. Apparently, the four loss functions produce convergent results, especially for the higher dimensioned solutions that fit the data well. At a given number of factors, the G^2 statistics are found to be of comparable magnitude. The RMSR values seem little influenced by the choice of loss function.

The RMSR values among the four loss functions vary between 0.034 and 0.039 for the 3-factor solution and approximate the expected standard error of correlation estimates (see the section on Asymptotic Sampling Variance of Correlation Coefficients in Phase III: Data Analysis). This suggests a good fit. The 4-factor solution, on the other hand, could not be reliably estimated from the current data: Both weighted loss functions produce Heywood cases. The ULS and ML estimates are also rather close to a Heywood solution as the uniqueness estimates for Word Knowledge are not significantly different from zero.

Table 8. Fit of Exploratory Factor Models for the Ten ASVAB Scales, Using Pairwise Deletion

		(N Assumed: 701)							
		$AV = \frac{(1-rho^2)^2}{n}$		$AV = \frac{1}{n}$		ULS		ML	
# Dims.	df	G^2	RMSR	G^2	RMSR	G^2	RMSR	G^2	RMSR
1	35	1604.43	.155	1428.86	.151	1454.07	.145	1146.49	.147
2	26	481.08	.063	441.76	.060	412.54	.054	383.22	.055
3	18	255.64	.039	228.81	.037	227.16	.034	198.80	.038
4	11	47.51	.017	46.61	.016	47.16	.016	46.68	.016
		(Heywood case)		(Heywood case)		(near Heywood)		(near Heywood)	
5	5	9.88	.006	9.69	.006	10.01	.006	not converged	
		(Heywood case)		(Heywood case)		(Heywood case)		(Heywood case)	

The G^2 values appear rather large, even for the 4-factor solutions. This effect may be due to matrix sampling or, more likely, to nonrandomized sampling inherent to the recruitment procedures for Air Force personnel. In the latter case, one could expect the G^2 statistic to be inflated by a cluster effect of approximately 2.5. Even after correction for clustering, the fit G^2 for the 3-factor solution still indicates a misfit.

The inconsistency of these results precludes a clear-cut decision about the dimensionality of the factor space. Although earlier analysis of a nationally representative sample (Bock & Moore, 1986) gave support to a 4-factor solution, the current sample appears to generate reasonable results only for three latent factors.

Table 9 shows the factor loadings, uniqueness, and factor intercorrelations for the Promax rotated 3-factor model estimated by DWLS with complex weights. The three factors are correlated, but otherwise clearly identifiable. Factor 1 taps School Attainment as expressed by performance differences in Word Knowledge, Paragraph Comprehension, General Science, and Mathematics Knowledge. The second factor represents Speed, with high loadings on Numerical Operations and Coding Speed, and a moderate loading on Arithmetic Reasoning. Factor 3 is Technical Knowledge measured by the subtests Auto and Shop Information, Mechanical Comprehension, and Electronics Information.

Table 9. Three-Factor Solution for the ASVAB Data, Pairwise Deletion, Complex Weights, Promax Rotation

	1	2	3	Uniqueness
		Factor Loadings		
General Science	.602	-.160	.269	.423
Arithmetic Reasoning	.338	.414	.266	.390
Word Knowledge	.965	-.258	-.194	.393
Paragraph Comprehension	.574	.096	-.083	.671
Numerical Operations	-.157	.899	-.055	.279
Coding Speed	-.123	.764	-.075	.474
Auto and Shop	-.240	-.063	.972	.289
Mathematical Knowledge	.515	.383	-.029	.447
Mechanical Comprehension	.077	.022	.703	.426
Electronics	.142	-.061	.665	.432
		Factor Correlations		
1	1.000			
2	.409	1.000		
3	.632	.112		1.000

Bock and Moore (1986) found a separate "Quantitative Attainment factor with dominant loadings on Arithmetic Reasoning and Mathematics Knowledge" (p. 200) and with a lesser loading on Mechanical Comprehension. In the present sample, Arithmetic Reasoning and Mathematics Knowledge are absorbed, instead, into the more general School Attainment factor.

The failure to obtain admissible estimates for a four-dimensional factor solution gives reason for some concern. It is of considerable practical concern for personnel selection whether Quantitative Attainment is separate from Verbal Attainment, or whether both can be subsumed under a general School Attainment factor. Both areas of competence show different growth curves, with Verbal Knowledge increasing over a person's lifetime but Quantitative Attainment generally decreasing after the end of formal schooling. Technical personnel must generally show good quantitative facilities, whereas verbal abilities are much more important in social and administrative occupations. Mismatching personnel and occupational requirements can be costly. This is why we dedicate some discussion to the dimensionality of the latent factor space. Possible causes for a change in the number of factors can be (a) modification of the correlation structure due to matrix sampling and pairwise deletion, (b) lack of information (precision) of the correlation matrix, or (c) real differences in the analyzed correlation structures.

ASVAB Subtests, Using Listwise Complete Data. Because the operational ASVAB (together with Booklets 1 and 2) was oversampled by a factor of three, a reasonably large sample size of 701 is maintained after listwise deletion. This permits the investigation of whether the dimensionality of the ASVAB subtests was affected by matrix sampling and pairwise deletion.

Factor models with one through five dimensions were calculated using ULS and ML estimation methods. The fit statistics for these stepwise analyses are exhibited in Table 10. The G^2 statistics and RMSR values for the two fit functions are essentially identical to those obtained in the previous analyses of the pairwise complete correlation matrix. The three-dimensional solutions yield acceptable RMSR values, but the G^2 statistics still tend to be on the large side. Neither of the higher dimensional factor models gives acceptable estimates. Though the 4-factor model produces a Heywood solution when estimated by ULS, it produces a uniqueness estimate of essentially 0.0 for Word Knowledge when estimated by ML, while the 5-factor model does not converge at all.

In conclusion, the number of ASVAB factors is not affected to a noticeable degree by matrix sampling or pairwise deletion of missing data.

Table 10. Fit of Exploratory Factor Models for the Ten ASVAB Scales, Using Listwise Complete Data

		(N = 701)			
		ULS		ML	
# Dims.	df	G^2	RMSR	G^2	RMSR
1	35	1287.49	.136	1027.20	.137
2	26	373.70	.053	355.39	.053
3	18	223.86	.035	190.61	.037
4	11	(Heywood case)		40.52	.015
5	5	not converged (Heywood case)		not converged (Heywood case)	

Relation to the ASVAB Factors in "Profile of the American Youth." The question remains whether the current ASVAB correlation matrix is not estimated at a high enough precision to support a 4-factor structure or whether Bock and Moore (1986) worked from a different correlation structure. Fortunately, Bock and Moore (p. 199) published the factor solution completely so that a truly confirmatory analysis can provide the definitive answer.

Using the listwise complete ASVAB data and ML estimation, the 4-factor solution by Bock and Moore (1986) is not supported in its entirety by the present data (G^2 = 459.76, df = 55, RMSR = 0.173). The model fits better when adjustments for sample-specific differences in reliability are introduced (G^2 = 223.36, df = 35, RMSR = 0.206), but neither off-diagonal nor the diagonal elements of the correlation matrix are reproduced very well. Finally, allowing the six factor intercorrelations to vary gives acceptable model fit (G^2 = 80.77, df = 29, RMSR = 0.033). The estimated factor correlation matrix differs considerably from the Bock and Moore solution.

These results suggest that lack of precision is not the reason why the ASVAB data fail to support a 4-factor solution. The correlation matrix for the current sample is simply not compatible with the factor solution from the national sample--even after the communalities of the ASVAB subscale variables were re-estimated for the new sample. We must conclude that differences in the sample correlation structure itself limit the factor model for the current ASVAB sample to only three dimensions.

At this point, we can only make conjectures about the source of difference between the correlation structures. First, the current sample of Air Force recruits is selective, not representative of the national distribution of potential applicants. The sample is 86% male, and applicants at the lower end of the ability spectrum were largely eliminated during the recruitment and enlistment processes. Considerable clustering is associated with Gender: Female recruits in this sample, for instance, are generally more educated and are more likely to be Afro-American than are their male counterparts. Gender is also a well-known determinant of individual differences in the ASVAB. Given equal schooling, males are advantaged in Arithmetic Reasoning, Auto and Shop Information, Mechanical Comprehension, Mathematics Knowledge, and Electronics Information, while females tend to excel in Paragraph Comprehension, Numerical Operations, and Coding Speed (Bock & Moore, 1986). In a more gender-balanced sample, such performance differences can generate the fourth factor that was missing in the current sample, which is almost entirely male.

Second, Bock and Moore eliminated major demographic variation (schooling, gender, socio-economic status, ethnic group) by analyzing a pooled within-group correlation matrix. It is quite conceivable that the Quantitative Attainment factor becomes detectable only after schooling effects are partialed out.

In a larger sample, the two conjectures could easily be tested: the first, by reweighting the sample; the second, by analyzing the pooled within-group correlation matrix of the present sample. We do not, however, advise these kinds of reconstructive methods when, as in the present case, many subgroup sample sizes would drop down to two-digit figures.

In the final analysis, the 3-factor structure provides an acceptable description of the ASVAB correlations in the current sample of Air Force recruits. The four-dimensional factor model, on the other hand, describes a representative sample of the American Youth independent of any decision to join the Armed Services.

Kit Reference Tests. The pairwise complete correlation matrix for the Kit reference tests happens to be indefinite. As a consequence, the distribution of the computed G^2 statistic is unknown; thus, these values should be used only in a heuristic way. A second consequence is that strict ML estimation is not possible. A ridge of 1.0 added to the diagonal values of the correlation matrix allows some quasi-ML estimation as discussed in the Data Analysis section on Exploratory Factor Analysis. Because adding the ridge appears to yield rather extreme G^2 values, assessment of fit must rely completely on the RMSR values.

The stepwise fit statistics for factor models of one through six dimensions are shown in Table 11. The 5-factor and 6-factor solutions all give RMSR values in the desired range between 0.050 and 0.067. In that the final aim is to use the Kit factors as predictors for the

ASVAB subtests, one should extract as many factors as the data can support. The 6-factor model fits the data fairly well and is readily interpretable. Attempts to extract seven or more factors resulted in Heywood solutions, almost certainly caused by doublet factors arising from the two-indicator measurement design for each of the 23 Kit scales. Needless to say, the data did not support the implied 23-factor model for the Kit.

Table 11. Fit of Exploratory Factor Models for the 46 Kit Reference Tests

		(N Assumed: 220)							
		$AV = \frac{(1-rho^2)^2}{n}$		$AV = \frac{1}{n}$		ULS		ML*	
# Dims.	df	G^2	RMSR	G^2	RMSR	G^2	RMSR	G^2	RMSR
1	989	4773.42	.111	4550.14	.110	4576.98	.108	715.17	.108
2	944	3568.64	.088	3280.78	.087	3296.20	.085	540.02	.085
3	900	3536.79	.082	2958.79	.077	2924.20	.075	459.38	.075
4	857	3287.84	.071	2688.57	.068	2641.43	.066	393.42	.066
5	815	2925.09	.064	2423.95	.062	2469.57	.060	348.31	.060
6	774	2744.46	.059	2215.49	.057	2305.55	.055	309.56	.055

*Ridge constant = 1.0.

Table 12 shows the Promax rotated 6-factor solution for the Kit reference tests, extracted by DWLS using complex weights.

Factor 1 is the typical Spatial Orientation factor, with prominent loadings on Paper Folding (VZ-2), Surface Development (VZ-3), Hidden Patterns (CF-2), Copying (CF-3), Card Rotations (S-1), Cube Comparisons (S-2), Maze Tracing Speed (SS-1), Map Planning (SS-3), Toothpicks (XF-1), and Storage (XF-3) tests. This factor also shows moderate loadings on the Gestalt Completion (CS-1), Letter Sets (I-1), Figure Classification (I-3), Calendar (IP-1), Following Directions (IP-2), Building Memory (MV-2), Arithmetic Aptitude (RG-1), Necessary Arithmetic Operations (RG-3), Diagramming Relationships (RL-2), Combining Objects (XU-1), and Making Groups (XU-3) tests. The Kit classification assigns many of these latter tasks to presumably nonspatial factors like Reasoning, Induction, etc.

Table 12. Exploration Factor Solution for the 46 *Kit* Reference Tests, PROMAX Rotation

	Factor Loadings 1 Spatial Orientation	2 Verbal Memory	3 Associative Memory	4 Figural Fluency	5 Verbal Fluency	6 Number/ Speed	Uniqueness
1 CF2	.531	-.094	.026	-.031	.087	.064	.644
2 CF3	.740	-.106	-.067	.050	.079	.014	.450
3 CS1	.449	-.179	.035	-.204	.113	-.197	.757
4 CS2	.172	-.108	-.169	-.210	.248	.074	.736
5 CV1	-.025	.055	.170	-.216	.279	.331	.572
6 CV3	-.168	-.018	.110	-.273	.434	.368	.519
7 FA1	-.032	.088	.056	.046	.703	-.124	.508
8 FA2	-.057	.131	-.039	.013	.708	-.122	.540
9 FE1	.041	.023	.019	.123	.573	.042	.573
10 FE2	.048	-.064	.035	.162	.529	.007	.645
11 FF1	-.049	.158	.137	.948	.041	.067	.102
12 FF2	.008	-.085	.050	.650	.144	.085	.478
13 FI1	-.040	.045	.101	.338	.484	-.063	.621
14 FI3	.042	-.075	-.061	.259	.576	-.016	.595
15 FW1	-.130	.000	.078	-.073	.611	.155	.552
16 FW2	-.172	.105	-.054	-.072	.727	.112	.478
17 I1	.343	.156	.154	-.093	.103	.187	.536
18 I3	.481	-.067	-.131	.084	-.018	.089	.781
19 IP1	.339	.460	-.068	-.036	.120	.062	.491
20 IP2	.346	.411	-.001	-.048	.106	.038	.523
21 MA1	-.106	.033	.883	.079	.014	-.102	.334
22 MA2	-.062	.038	.886	.147	-.029	-.182	.371
23 MS1	-.240	.592	.164	.139	.114	.206	.519
24 MS3	-.135	.580	.170	.191	.096	.124	.553
25 MV2	.390	.096	.547	.013	-.237	-.097	.537
26 MV3	.279	.060	.242	-.063	.057	-.139	.795
27 N1	-.025	.170	-.164	.102	-.035	.860	.340
28 N3	-.150	.190	-.131	.084	-.095	1.027	.132
29 P1	-.024	-.203	.078	-.115	.122	.501	.650
30 P2	.114	-.075	.004	-.009	-.045	.496	.727
31 RG1	.480	.475	-.104	.107	-.128	.349	.355
32 RG3	.410	.431	.043	.109	-.050	.111	.515
33 RL1	.186	.221	.010	.012	.075	.019	.854
34 RL2	.474	.254	.056	-.096	.114	-.071	.525
35 S1	.666	.047	-.119	.046	-.127	.115	.606
36 S2	.717	.020	-.008	-.003	-.038	-.019	.516
37 SS1	.599	-.188	-.005	.145	.014	.006	.634
38 SS3	.543	.067	-.006	-.017	-.095	.265	.580
39 V1	.013	.396	-.228	-.153	.584	-.216	.442
40 V2	-.032	.436	-.098	-.153	.519	-.175	.464
41 VZ2	.788	.048	.034	.007	-.122	-.154	.474
42 VZ3	.890	.032	-.042	-.067	-.075	-.135	.320
43 XF1	.526	.041	.041	-.060	-.041	-.039	.717
44 XF3	.686	.067	.007	-.084	-.033	-.196	.553
45 XU1	.387	-.085	-.099	.151	.373	-.151	.664
46 XU3	.325	.046	-.077	.095	.387	-.006	.624

Factor Correlations

	1 Spatial Orientation	2 Verbal Memory	3 Associative Memory	4 Figural Fluency	5 Verbal Fluency	6 Number/ Speed
1 Spatial Orientation	1.000					
2 Verbal Memory	.292	1.000				
3 Associative Memory	.386	.243	1.000			
4 Figural Fluency	-.034	-.248	-.085	1.000		
5 Verbal Fluency	.508	.330	.413	.089	1.000	
6 Number/Speed	.350	.081	.465	.111	.453	1.000

Factor 2 assesses Verbal Memory. It has moderate loadings on several tasks which profit from the ability to manipulate verbal content in short-term memory. Indicators for Factor 2 are the Calendar (IP-1), Following Directions (IP-2), Auditory Number Span (MS-1), Auditory Letter Span (MS-3), Arithmetic Aptitude (RG-1), Necessary Arithmetic Operations (RG-3), Vocabulary I (V-1) and Vocabulary II (V-2) tests.

Factor 3 expresses Associative Memory, showing high loadings on the Picture-Number (MA-1) and Object-Number (MA-2) tasks, as well as a moderate loading on the Building Memory (MV-2) test.

Factor 4, Figural Fluency, is also a minor dimension, a triplet factor that addresses individual differences in the active production of spatial relations or ornamental designs. It shows a high loading on the Ornamentation Test (FF-1), and moderate to small loadings on the Elaboration Test (FF-2) and the Topics Test (FI-1), respectively.

Factor 5 is the familiar Verbal Fluency dimension. Its dominant indicators are the Controlled Associations (FA-1), Opposites (FA-2), and Word Beginnings (FW-2) tests. The factor also has moderate loadings on the Making Sentences (FE-1), Arranging Words (FE-2), Thing Categories (FI-3), Word Endings (FW-1), and Vocabulary I and II (V-1, V-2) tests. Smaller loadings are found for tests involving Incomplete Words (CV-3), Topics (FI-1), Combining Objects (XU-1), and Making Groups (XU-3).

The last factor (Factor 6), Number/Speed, measures both perceptual speed and the rate of performing simple numeric operations. The highest loading variables are the Addition Test (N-1) and the Subtraction and Multiplication Tests (N-3). The Finding A's (P-1) and the Number Comparison (P-2) tests show moderate loadings, while the Scrambled Words (CV-1), Incomplete Words (CV-3), and Arithmetic Aptitude (RG-1) tasks still receive a small contribution from this factor.

Three Kit tests, Concealed Words (CS-2), Map Memory (MV-3), and Nonsense Syllogisms (RL-1), do not appear to be particularly well represented by any of the factors.

Joint Analysis of ASVAB and Kit Subtests. A simultaneous factor analysis of the 10 ASVAB subtests and the 46 Kit reference tests can address the question of whether the 3-factor domain of the ASVAB lies within a subspace of the 6-dimensional Kit domain. If more than six dimensions are required to describe the correlation matrix of all 56 tests, this would establish excellent evidence that the ASVAB factors are not fully part of the Kit space. Table 13 shows that the RMSR statistics for the 4- through 6-factor solutions are identical at three decimal digits to the 46-test Kit analysis in Table 10. The ASVAB factor space appears to be completely embedded in the Kit.

Table 13. Fit of Joint Exploratory Factor Models for the Ten ASVAB and 46 Kit Tests

		(N Assumed: 220)							
		$AV = \frac{(1-rho^2)^2}{n}$		$AV = \frac{1}{n}$		ULS		ML*	
# Dims.	df	G^2	RMSR	G^2	RMSR	G^2	RMSR	G^2	RMSR
1	1484	8748.86	.125	8059.90	.120	4822.03	.117	1131.70	.118
2	1429	6468.67	.093	5859.68	.091	5755.92	.088	849.09	.088
3	1375	5561.41	.080	4864.02	.077	4716.68	.074	699.21	.074
4	1322	5497.56	.072	4578.73	.069	4365.44	.066	617.57	.066
5	1270	4915.23	.065	4111.91	.063	4073.89	.061	553.38	.061
6	1219	4669.71	.060	3934.04	.058	3987.67	.057	507.28	.057

*Ridge constant = 1.0.

Table 14 displays the factor loadings, uniqueness coefficients, and factor intercorrelations of the Promax rotated 6-factor DWLS solution using complex weights. Although all of the four 6-factor solutions have about equally good fit, the DWLS solution with complex weights is given here, mainly because its fit function is most comparable to the 46-test Kit factor solution in Table 11.

The solution comprises an essentially unchanged factor structure for the 46 Kit reference tests, almost exactly as described in the previous section. Therefore, the loading structure of the Kit reference tests need not be discussed again. The factors appear stable enough to describe the ASVAB subtest in terms of the six known factors.

Factor 6, Verbal Memory, makes the most general contribution to the ASVAB subtests. It shows appreciably large weights on General Science, Arithmetic Reasoning, Word Knowledge, and Electronics Information. Further minor loadings are found for Paragraph Comprehension, Auto and Shop Information, Mathematics Knowledge, and Mechanical Comprehension. The factor appears to be strongly related to the concept of School Attainment.

Factor 1, Spatial Orientation, has the expected large contribution for Mechanical Comprehension, and moderate contributions for Arithmetic Reasoning, Auto and Shop Information, and Electronics Information. The Kit Number/Speed factor (Factor 6) affects exclusively Numerical Operations and Coding Speed, while the Verbal Fluency factor exhibits a minor secondary component on the Word Knowledge test. Finally, the ASVAB subtests do not share any communality with the Kit factors Figural Fluency and Associative Memory.

Table 14. Exploratory Factor Solution for the 10 ASVAB and 46 Kit Reference Tests Combined, PROMAX Rotation

	Factor Loadings						
	1	2	3	4	5	6	
	Spatial Orientation	Figual Fluency	Number/ Speed	Verbal Fluency	Associative Memory	Verbal Memory	Uniqueness
1 GS	.147	.050	-.086	.161	-.175	.668	.426
2 AR	.326	-.013	.282	-.199	.224	.517	.254
3 WK	-.155	-.086	-.048	.454	-.210	.716	.346
4 PC	-.051	-.008	.121	.165	.058	.471	.669
5 NO	.030	.204	.849	-.043	-.063	.048	.348
6 CS	.091	.136	.789	-.029	-.108	-.010	.439
7 AS	.439	.281	-.232	-.254	-.127	.431	.355
8 MK	.189	-.022	.256	.029	.252	.368	.414
9 MC	.621	.116	-.256	-.127	.004	.348	.356
10 EI	.319	.209	-.118	-.083	-.179	.579	.406
11 CF2	.544	-.026	.091	.104	-.054	-.034	.646
12 CF3	.753	.008	.063	.118	-.107	-.143	.445
13 CS1	.473	-.173	-.207	.102	-.081	-.002	.777
14 CS2	.283	-.163	-.067	.254	.120	-.077	.763
15 CV1	.070	-.180	.136	.327	.205	-.040	.604
16 CV3	-.073	-.227	.255	.411	.052	.058	.557
17 FA1	.028	.097	-.119	.627	.070	.142	.542
18 FA2	-.028	.040	-.124	.672	-.014	.176	.549
19 FE1	.067	.134	.031	.600	.007	.026	.560
20 FE2	.114	.214	-.019	.539	.042	-.093	.628
21 FF1	-.177	.891	.205	.109	.245	-.003	.223
22 FF2	-.058	.709	.199	.152	.088	-.108	.458
23 FI1	-.032	.359	-.034	.462	.165	.001	.641
24 FI3	.064	.345	.003	.517	-.032	-.006	.608
25 FW1	-.017	-.013	.078	.590	.054	-.010	.572
26 FW2	-.125	-.033	.055	.690	-.037	.161	.493
27 I1	.359	-.165	.151	.151	.189	.046	.511
28 I3	.454	.054	.141	.035	-.177	-.065	.784
29 IP1	.220	-.068	.152	.099	.035	.443	.530
30 IP2	.260	-.101	.033	.131	.099	.389	.531
31 MA1	-.062	.130	-.157	.036	.903	-.143	.424
32 MA2	-.040	.197	-.273	-.012	1.016	-.147	.360
33 MS1	-.265	.124	.092	.212	.387	.297	.625
34 MS3	-.169	.121	-.027	.245	.395	.219	.686
35 MV2	.412	-.013	-.182	-.154	.606	-.103	.557
36 MV3	.277	-.051	-.112	.050	.211	.083	.809
37 N1	-.163	.068	.968	-.012	-.191	.232	.310
38 N3	-.188	.095	1.026	-.033	-.164	.101	.231
39 P1	.078	-.071	.413	.157	-.019	-.198	.695
40 P2	.137	-.024	.537	.024	-.114	-.118	.696
41 RG1	.226	.067	.491	-.234	.073	.655	.186
42 RG3	.277	.036	.230	-.043	.110	.411	.504
43 RL1	.115	.014	-.004	.101	.081	.224	.855
44 RL2	.410	-.160	-.032	.115	.092	.272	.525
45 S1	.614	-.007	.112	-.039	-.114	.029	.624
46 S2	.700	-.071	-.041	.014	.016	-.006	.517
47 SS1	.653	.115	.012	.099	-.063	-.312	.592
48 SS3	.541	-.033	.212	-.024	-.014	.025	.598
49 V1	-.085	-.180	-.136	.550	-.277	.596	.381
50 V2	-.131	-.122	-.073	.461	-.104	.611	.426
51 VZ2	.731	-.053	-.163	-.098	.096	.063	.470
52 VZ3	.822	-.136	-.097	-.043	-.047	.108	.329
53 XF1	.514	-.087	-.049	-.034	.079	.017	.718
54 XF3	.649	-.089	-.211	-.018	.022	.136	.532
55 XU1	.394	.185	-.125	.346	-.109	.007	.662
56 XU3	.315	.091	.054	.365	-.086	.111	.625

Table 14. (Concluded)

	Factor Correlations					
	1	2	3	4	5	6
	Spatial Orientation	Figural Fluency	Number/ Speed	Verbal Fluency	Associative Memory	Verbal Memory
1 Spatial Orientation	1.000					
2 Figural Fluency	.068	1.000				
3 Number/Speed	.324	-.129	1.000			
4 Verbal Fluency	.382	-.049	.499	1.000		
5 Associative Memory	.370	-.274	.585	.468	1.000	
6 Verbal Memory	.420	-.032	.014	.253	.288	1.000

Kit Reference Tests and the Two AFQT Scales. A simultaneous factor analysis of the two AFQT scales and the 46 Kit reference tests was performed. Before proceeding to this analysis, two cautionary remarks are appropriate.

The AFQT scores are computed as linear combinations of several ASVAB subtests. By averaging systematic variation, both AFQT scores can be expected to be more reliable than most individual tests in this study. In addition, the two AFQT scales largely share the same components. This creates an artificial doublet that will likely influence the factor structure.

Secondly, because the correlation structure between the two AFQT scales and the 46 Kit tests was not directly observed in the present study but instead extrapolated from the subtest components of the AFQT scales, factor extraction is limited to ULS and "heuristic" ML methods.

The stepwise fit statistics for up to six exploratory factors are shown in Table 15. The RMSR statistics are reasonably small for four-, five-, and six-dimensional solutions. Table 16 shows the 6-factor ULS solution, after Promax rotation. The six factors are again recognized as Spatial Orientation, Verbal Fluency, Number/Speed, Figural Fluency, Associative Memory, and Verbal Memory. The last factor appears to be in a somewhat different orientation than in the previous analysis, which is signaled by the disappearing loadings on Vocabulary I and II, and by the increased correlation with the Verbal Fluency factor. The modification of the factor structure is attributable to introducing two AFQT scales into the analysis. The AFQT doublet has essentially "pulled over" the verbal factor towards its own location. As a consequence, the AFQT scales appear to load only, and dominantly, on the new verbal factor.

Table 15. Fit of Joint Exploratory Factor Models For the Two AFQT and 46 Kit Scales

		(N = 220)			
		ULS		ML*	
# Dims.	df	G^2	RMSR	G^2	RMSR
1	1080	5347.68	.107	786.06	.108
2	1033	4153.03	.086	610.93	.086
3	987	3677.84	.075	518.64	.075
4	942	3207.37	.066	441.36	.067
5	898	3024.50	.061	391.01	.061
6	855	2886.91	.055	345.50	.055

*Ridge constant = 1.0.

Confirmatory Factor Analyses

Restricted Factor Structure for the Kit Reference Tests. Finding a well-fitting restricted factor solution for the Kit tests was not an easy task, even though the work started from the Promax solution. First of all, setting all apparently insignificant factor loadings to zero produced Heywood cases. Inspection of residuals suggested augmenting the factor model by correlated error terms for some pairs of reference tests. Such correlated uniqueness terms can make good conceptual sense because they absorb most variation that would otherwise lead to doublet factors (see Browne, 1980, for a related factor model). Though adding a few such correlated error terms improved the model fit dramatically, further Heywood cases prevented us from systematically specifying one such term for each of the 23 Kit "factors." The final selection of correlated error terms had to be determined inductively.

Table 17 shows the final restricted factor model for the Kit data. The zero entries in the factor loading matrix and the unit diagonal in the factor correlation matrix are restricted parameters; all other values in Table 17 are estimated. The fit of the model is quite reasonable (G^2 = 2712.63, df = 944, RMSR = 0.072) when estimated by DWLS using complex weights. There are eight correlated error components to model specific doublet factors (under the heading "Unique Covariance"). The six major Kit factors are defined by the pattern of zero loadings. The free, estimated factor loadings remain quite close to the exploratory solution in Table 12; that is, the restricted factor structure is practically identical to that of the Promax solution.

Table 16. Exploratory Factor Solution for the Two AFQT Scales and 46 Kit Reference Tests, Promax Rotation

	Factor Loadings						
	1	2	3	4	5	6	
	Spatial Orientation	Verbal Fluency	Number/ Speed	Figural Fluency	Associative Memory	Verbal Memory	Uniqueness
1 AFQT1	.071	.176	.185	.051	.013	.728	.138
2 AFQT2	.108	.213	.040	-.017	.048	.759	.060
3 CF2	.567	-.012	.087	.024	-.003	.000	.644
4 CF3	.730	.047	.046	.048	-.112	-.071	.494
5 CS1	.425	.164	-.182	-.156	-.029	-.083	.785
6 CS2	.236	.339	.042	-.232	.085	-.218	.686
7 CV1	.042	.444	.341	-.252	.083	-.123	.525
8 CV3	-.156	.532	.403	-.200	-.004	-.007	.508
9 FA1	-.060	.660	-.126	.219	.139	.005	.489
10 FA2	-.082	.692	-.166	.146	-.005	.082	.543
11 FE1	.064	.525	.083	.221	-.017	-.047	.575
12 FE2	.121	.447	.019	.302	.006	-.163	.631
13 FF1	-.057	-.122	.113	.688	.149	.081	.508
14 FF2	.037	.004	.108	.539	-.024	-.050	.668
15 FI1	-.071	.297	-.086	.515	.163	.098	.570
16 FI3	.049	.395	.010	.431	-.062	-.020	.596
17 FW1	-.107	.599	.178	.044	.071	-.092	.577
18 FW2	-.160	.812	.081	.037	-.123	.010	.450
19 I1	.260	.203	.153	-.104	.175	.138	.544
20 I3	.493	-.096	.102	.118	-.146	.009	.774
21 IP1	.237	.182	.070	-.094	-.059	.439	.510
22 IP2	.244	.228	.004	-.094	-.023	.380	.533
23 MA1	-.109	.002	-.005	.104	.823	-.024	.397
24 MA2	-.109	-.065	-.075	.156	.859	.037	.382
25 MS1	-.221	.255	.260	.034	.069	.293	.706
26 MS3	-.132	.317	.065	.089	.143	.161	.772
27 MV2	.341	-.209	-.085	-.047	.644	.019	.461
28 MV3	.239	-.001	-.120	-.029	.235	.161	.786
29 N1	-.153	-.102	.771	.131	-.056	.391	.358
30 N3	-.182	-.069	.900	.107	-.071	.221	.257
31 P1	.020	.096	.529	-.030	.054	-.157	.651
32 P2	.145	-.072	.507	-.008	.005	-.064	.716
33 RG1	.226	-.170	.290	.111	-.037	.792	.183
34 RG3	.280	-.025	.087	.060	.075	.458	.534
35 RL1	.181	.083	.055	.006	-.039	.184	.864
36 RL2	.366	.145	-.097	-.090	.092	.298	.532
37 S1	.691	-.194	.091	.076	-.141	.111	.581
38 S2	.705	-.044	-.045	.037	-.003	.052	.519
39 SS1	.683	-.012	.037	.156	.005	-.320	.565
40 SS3	.541	-.082	.260	-.027	.009	.066	.569
41 V1	-.035	.679	-.258	-.149	-.204	.266	.483
42 V2	-.060	.608	-.156	-.147	-.075	.257	.553
43 VZ2	.730	-.123	-.181	-.026	.099	.096	.479
44 VZ3	.869	-.099	-.166	-.047	-.035	.138	.297
45 XF1	.548	-.033	-.037	-.089	.044	.029	.692
46 XF3	.686	-.062	-.191	-.096	.004	.104	.540
47 XU1	.363	.312	-.162	.272	-.096	-.052	.658
48 XU3	.263	.247	-.012	.227	-.033	.193	.621

Table 16. (Concluded)

	Factor Correlations					
	1	2	3	4	5	6
	Spatial Orientation	Verbal Fluency	Number/ Speed	Figural Fluency	Associative Memory	Verbal Memory
1 Spatial Orientation	1.000					
2 Verbal Fluency	.544	1.000				
3 Number/Speed	.333	.415	1.000			
4 Figural Fluency	.066	.160	.177	1.000		
5 Associative Memory	.412	.439	.385	-.050	1.000	
6 Verbal Memory	.430	.472	.109	-.034	.324	1.000

Table 17. Restricted Factor Solution for the 46 Kit Reference Tests

	Factor Loadings						Uniqueness	
	1	2	3	4	5	6		
	Spatial Orientation	Figural Fluency	Number/ Speed	Verbal Fluency	Associative Memory	Verbal Memory	Var.	Cov.
1 CF2	.606	.000	.000	.000	.000	.000	.633	
2 CF3	.754	.000	.000	.000	.000	.000	.431	
3 CS1	.392	.000	.000	.000	.000	.000	.847	>.216
4 CS2	.231	.000	.209	.175	.000	.000	.798	
5 CV1	.000	.000	.366	.381	.000	.000	.616	>.187
6 CV3	.000	.000	.286	.378	.000	.000	.694	
7 FA1	.000	.000	.000	.709	.000	.000	.498	
8 FA2	.000	.000	.000	.633	.000	.000	.599	
9 FE1	.000	.000	.000	.672	.000	.000	.549	
10 FE2	.000	.000	.000	.602	.000	.000	.638	
11 FF1	.000	.680	.000	.000	.000	.000	.537	>.391
12 FF2	.000	.518	.000	.000	.000	.000	.731	
13 FI1	.000	.287	.000	.407	.000	.000	.678	>.184
14 FI3	.000	.351	.000	.415	.000	.000	.613	
15 FW1	.000	.000	.000	.647	.000	.000	.582	
16 FW2	.000	.000	.000	.692	.000	.000	.521	
17 I1	.394	.000	.233	.000	.000	.311	.534	
18 I3	.428	.000	.000	.000	.000	.000	.817	
19 IP1	.354	.000	.000	.000	.000	.439	.529	
20 IP2	.323	.000	.000	.000	.000	.522	.519	
21 MA1	.000	.000	.000	.000	.888	.000	.212	
22 MA2	.000	.000	.000	.000	.812	.000	.341	
23 MS1	.000	.000	.000	.000	.000	.606	.633	>.339
24 MS3	.000	.000	.000	.000	.000	.559	.688	

Table 17. (Concluded)

Factor Loadings

	1 Spatial Orientation	2 Figural Fluency	3 Number/ Speed	4 Verbal Fluency	5 Associative Memory	6 Verbal Memory	Uniqueness Var.	Uniqueness Cov.
25 MV2	.364	.000	.000	.000	.421	.000	.622	
26 MV3	.330	.000	.000	.000	.230	.000	.805	
27 N1	.000	.000	.897	.000	.000	.000	.196	
28 N3	.000	.000	.819	.000	.000	.000	.342	
29 P1	.000	.000	.568	.000	.000	.000	.677	>.186
30 P2	.000	.000	.489	.000	.000	.000	.761	
31 RG1	.449	.000	.262	.000	.000	.298	.461	
32 RG3	.409	.000	.000	.000	.000	.433	.536	
33 RL1	.214	.000	.000	.000	.000	.265	.850	>.079
34 RL2	.517	.000	.000	.000	.000	.314	.535	
35 S1	.617	.000	.000	.000	.000	.000	.620	
36 S2	.717	.000	.000	.000	.000	.000	.486	
37 SS1	.542	.000	.000	.000	.000	.000	.706	
38 SS3	.524	.000	.290	.000	.000	.000	.591	
39 V1	.000	.000	.000	.178	.000	.424	.689	>.383
40 V2	.000	.000	.000	.224	.000	.370	.704	
41 VZ2	.692	.000	.000	.000	.000	.000	.521	
42 VZ3	.789	.000	.000	.000	.000	.000	.377	
43 XF1	.526	.000	.000	.000	.000	.000	.723	
44 XF3	.634	.000	.000	.000	.000	.000	.598	
45 XU1	.309	.000	.000	.276	.000	.000	.764	
46 XU3	.295	.000	.000	.416	.000	.000	.646	

Factor Correlations

	1 Spatial Orientation	2 Figural Fluency	3 Number/ Speed	4 Verbal Fluency	5 Associative Memory	6 Verbal Memory
1 Spatial Orientation	1.000					
2 Figural Fluency	.162	1.000				
3 Number/Speed	.165	.246	1.000			
4 Verbal Fluency	.379	.315	.377	1.000		
5 Associative Memory	.219	.170	.365	.316	1.000	
6 Verbal Memory	.307	-.051	.373	.658	.345	1.000

However, the factor orientation has changed somewhat. Most factors are still positively correlated, but Verbal Fluency is now more removed from Spatial Orientation and is oriented closer towards Verbal Memory. These latter two factors are now correlated at 0.658. Due to the geometry of oblique spaces, factor loadings can apparently disappear when a solution becomes more oblique. This phenomenon reflects a trade-off between the estimates for the loadings and those for the factor correlations. The effect is most apparent with the Verbal

Fluency factor, where the factor loadings for Vocabulary I and II have now virtually disappeared. Projecting a result from the subsequent analyses, the orientation of the Verbal Fluency factor is generally very poorly defined. The factor is always identifiable, but its correlation pattern appears to keep changing.

In the following models, the interpretation of regression equations onto these oblique factor structures can become fairly complex, because factor loading and factor correlation patterns have to be simultaneously adhered to. Similar conceptual problems are demonstrated by Bock (1975, pp. 417-420) for the analysis of discriminant function coefficients.

Ten ASVAB Subtests Regressed on the Major Kit Factors. The multivariate regression model yields an inadmissible solution, with excessive residual covariance components for Word Knowledge. The factor model (shown in Table 18), on the other hand, provides an admissible solution at a reasonable fit (G^2 = 4813.40, df = 1389, RMSR = 0.074). To permit a limited modal test, a hybrid model was constructed from the regression model by restricting only the three residual covariance components for the General Science, Arithmetic Reasoning, and Word Knowledge subtests. This mixed model produced an admissible solution which fit equally well (G^2 = 4623.07, df = 1347, RMSR = 0.073) as the factor model, even though the individual parameter estimates for the Kit Figural Fluency and Vocabulary tests differ considerably. The data contain insufficient information to discriminate between the two models or to estimate the parameters reliably. Ideally, the sample size should have been larger or the model should have been better defined (so that additional restrictions could be imposed). For the time being, the estimated regression equations for the ASVAB subtests do not support very detailed conclusions.

Table 18. Ten ASVAB Subtests Regressed onto Six Major Kit Factors. Restricted Factor Model, Uncorrelated ASVAB Residuals

	Regression Equations						
	1	2	3	4	5	6	
	Spatial Orientation	Figural Fluency	Number/ Speed	Verbal Fluency	Associative Memory	Verbal Memory	Residual Variance
1 GS	.296	.337	-.128	-1.379	-.056	1.681	.418
2 AR	.641	-.043	.246	-.247	-.027	.489	.274
3 WK	-.011	.161	-.104	-1.011	.020	1.636	.349
4 PC	.127	.135	.080	-.555	.068	.908	.682
5 NO	.047	.454	.704	-.609	.160	.403	.333
6 CS	.045	.416	.669	-.660	.200	.406	.419
7 AS	.490	.683	-.322	-1.681	-.135	1.458	.327
8 MK	.402	-.020	.280	-.231	.123	.505	.431
9 MC	.671	.365	-.254	-.973	-.067	.951	.363
10 EI	.434	.550	-.179	-1.629	-.161	1.640	.405

Table 18. (Continued)

Factor Correlations

	1 Spatial Orientation	2 Figural Fluency	3 Number/ Speed	4 Verbal Fluency	5 Associative Memory	6 Verbal Memory
1 Spatial Orientation	1.000					
2 Figural Fluency	.181	1.000				
3 Number/Speed	.179	.254	1.000			
4 Verbal Fluency	.367	.465	.458	1.000		
5 Associative Memory	.241	.160	.293	.368	1.000	
6 Verbal Memory	.368	.178	.347	.906	.317	1.000

Factor Loadings

	1 Spatial Orientation	2 Figural Fluency	3 Number/ Speed	4 Verbal Fluency	5 Associative Memory	6 Verbal Memory	Uniqueness Var.	Uniqueness Cov.
1 CF2	.591	.000	.000	.000	.000	.000	.651	
2 CF3	.726	.000	.000	.000	.000	.000	.472	
3 CS1	.390	.000	.000	.000	.000	.000	.848	>.213
4 CS2	.243	.000	.113	.213	.000	.000	.813	
5 CV1	.000	.000	.254	.421	.000	.000	.661	>.203
6 CV3	.000	.000	.249	.400	.000	.000	.687	
7 FA1	.000	.000	.000	.682	.000	.000	.535	
8 FA2	.000	.000	.000	.601	.000	.000	.639	
9 FE1	.000	.000	.000	.656	.000	.000	.570	
10 FE2	.000	.000	.000	.567	.000	.000	.678	
11 FF1	.000	.513	.000	.000	.000	.000	.737	>.521
12 FF2	.000	.433	.000	.000	.000	.000	.813	
13 FI1	.000	.240	.000	.384	.000	.000	.709	>.197
14 FI3	.000	.419	.000	.331	.000	.000	.585	
15 FW1	.000	.000	.000	.628	.000	.000	605	
16 FW2	.000	.000	.000	.671	.000	.000	.549	
17 I1	.412	.000	.324	.000	.000	.189	.542	
18 I3	.399	.000	.000	.000	.000	.000	.841	
19 IP1	.390	.000	.000	.000	.000	.395	.578	
20 IP2	.372	.000	.000	.000	.000	.407	.585	
21 MA1	.000	.000	.000	.000	.895	.000	.199	
22 MA2	.000	.000	.000	.000	.805	.000	.352	
23 MS1	.000	.000	.000	.000	.000	.525	.725	>.435
24 MS3	.000	.000	.000	.000	.000	.462	.787	
25 MV2	.358	.000	.000	.000	.409	.000	.634	
26 MV3	.336	.000	.000	.000	.237	.000	.792	
27 N1	.000	.000	.879	.000	.000	.000	.228	
28 N3	.000	.000	.799	.000	.000	.000	.361	

Table 18. (Concluded)

	Factor Loadings							
	1	2	3	4	5	6	Uniqueness	
	Spatial Orientation	Figural Fluency	Number/ Speed	Verbal Fluency	Associative Memory	Verbal Memory	Var.	Cov.
29 P1	.000	.000	.555	.000	.000	.000	.692	>.171
30 P2	.000	.000	.527	.000	.000	.000	.722	
31 RG1	.571	.000	.255	.000	.000	.250	.345	
32 RG3	.453	.000	.000	.000	.000	.357	.548	
33 RL1	.206	.000	.000	.000	.000	.246	.860	>.094
34 RL2	.522	.000	.000	.000	.000	.269	.552	
35 S1	.507	.000	.000	.000	.000	.000	.643	
36 S2	.692	.000	.000	.000	.000	.000	.522	
37 SS1	.510	.000	.000	.000	.000	.000	.740	
38 SS3	.535	.000	.237	.000	.000	.000	.612	
39 V1	.000	.000	.000	-.901	.000	1.511	.372	>.076
40 V2	.000	.000	.000	-.769	.000	1.396	.406	
41 VZ2	.686	.000	.000	.000	.000	.000	.529	
42 VZ3	.786	.000	.000	.000	.000	.000	.382	
43 XF1	.523	.000	.000	.000	.000	.000	.727	
44 XF3	.642	.000	.000	.000	.000	.000	.588	
45 XU1	.335	.000	.000	.233	.000	.000	.776	
46 XU3	.276	.000	.000	.402	.000	.000	.681	

The estimated factor correlation between Verbal Fluency and Verbal Memory emerges as 0.906, rendering the factor correlation matrix as nearly singular. In a guarded interpretation of the regression weights, only the sum of the coefficients for Verbal Fluency and Verbal Memory should be considered, as the two factors are almost collinear. The net effect may be regarded as the impact of verbal knowledge.

Four subtests -- General Science, Auto and Shop Information, Mechanical Comprehension, and Electronics Information -- have a similar prediction pattern on the first three factors. All have positive weights on Spatial Orientation and Figural Fluency, negative weights on Number/Speed. The net Verbal contribution for Mechanical Comprehension and Electronics Information is virtually zero, whereas Auto and Shop Information has a negative and General Science a positive net weight on the Verbal factors. Performance on all four subtests seems to be aided by the ability to comprehend and manipulate spatial information. The differential impact of the Verbal net effect may reflect the phenomenon that acquisition of Auto and Shop knowledge occurs, in large part, outside the school system and competes with the pursuit of academic objectives. Science information, in contrast, is learned primarily through the formal school system.

Among the other ASVAB subtests, the Word Knowledge and Paragraph Comprehension subtests are predicted exclusively by the Verbal factors. Note, however, that Paragraph Comprehension is poorly predicted altogether, with only 32% of its total variance accounted for. The subtests Arithmetic Reasoning and Mathematics Knowledge both have large regression weights on Spatial Orientation and moderate weights on the Number/Speed and Verbal factors. Finally, Numerical Operations and Coding Speed appear to combine a mixture of Fluency, Verbal, and Number/Speed components; but only the Number/Speed factor has a sizable contribution. The regression weights on Fluency and Verbal factors appear to describe suppressor effects. As in earlier analyses, the Associative Memory factor has no part at all in the prediction of the ASVAB subtests.

The regression of the ASVAB subtests suggests a 4-component model similar to that of Bock and Moore (1986). However, because the Figural Fluency factor is relatively minor, the evidence supporting the fourth component is weak.

Hierarchical Factor Model for the ASVAB Regressed onto the Major Kit Factors. The model outlined in Figure 1, Panel A, is not estimable with current data. A negative estimate for the structural residual of the second-order factor makes the solution inadmissible. This Heywood case can, as before, be traced to the ASVAB subtest Word Knowledge.

Table 19 presents a boundary solution, defined by forcing the residual variance terms for the higher-order factor and for School Attainment equal to zero. The fit of this solution (in RMSR terms) is 30% worse than the factor regression model above, and is 23% worse than the fit of the multiple factor model below (G^2 = 4780.93, df = 1430, RMSR = 0.096). The hierarchical model produces residual correlations in excess of 0.3 for tests pertaining to the Speed factors and to some of the Fluency indicators. It does not fit the data particularly well.

Major ASVAB Factors Regressed onto Major Kit Factors. The restricted 3-factor ASVAB model regressed onto six major Kit factors produces a negative residual variance component for the School Attainment factor. Table 20 presents only a border solution, with the residual variance and covariance components for School Attainment fixed at zero. The fit of the modified model is acceptable (G^2 = 4739.96, df = 1419, RMSR = 0.078).

The two sets of factors in the linear equation system are easily recognized in terms of the previous discussions. The (dependent) ASVAB factors are School Attainment, Speed, and Technical Knowledge; the (independent) Kit factors are Spatial Orientation, Figural Fluency, Number/Speed, Verbal Fluency, Associative Memory, and Verbal Memory. The Kit factor structure matches almost completely the solution shown in Table 18. Unfortunately, this means that the regression weights for Verbal Fluency and Verbal Memory are highly correlated and should, again, be combined in the interpretation.

Table 19. Hierarchical ASVAB Factor Model Regressed onto Six Major Kit Factors. Boundary Solution

First-Order Factor Loadings and Uniqueness for ASVAB Subtests

	1 School Attainment	2 Speed	3 Technical Knowledge	Residual Variance
1 GS	.673	.000	.000	.547
2 AR	.743	.171	.000	.350
3 WK	.641	.000	.000	.589
4 PC	.543	.000	.000	.706
5 NO	.000	.871	.000	.241
6 CS	.000	.724	.000	.476
7 AS	.000	.000	.684	.532
8 MK	.614	.280	.000	.451
9 MC	.000	.000	.843	.289
10 EI	.000	.000	.770	.408

Second-Order Factor Structure for ASVAB Subtests

	H	Residual Variance
School Attainment	1.000	.000
Speed	.273	.925
Technical Knowledge	.557	.690

Regression Equation for Second-Order Factor

	1 Spatial Orientation	2 Figural Fluency	3 Number/ Speed	4 Verbal Fluency	5 Associative Memory	6 Verbal Memory	Uniqueness
H	.345	.046	.009	-.109	-.009	.513	.000

Table 19. (Continued)

Factor Loadings for the Kit

		1 Spatial Orientation	2 Figural Fluency	3 Number/ Speed	4 Verbal Fluency	5 Associative Memory	6 Verbal Memory	Uniqueness Var.	Uniqueness Cov.
1	CF2	.600	.000	.000	.000	.000	.000	.640	
2	CF3	.739	.000	.000	.000	.000	.000	.454	
3	CS1	.397	.000	.000	.000	.000	.000	.843	>.214
4	CS2	.236	.000	.225	.158	.000	.000	.794	
5	CV1	.000	.000	.369	.359	.000	.000	.628	>.196
6	CV3	.000	.000	.258	.397	.000	.000	.694	
7	FA1	.000	.000	.000	.720	.000	.000	.481	
8	FA2	.000	.000	.000	.625	.000	.000	.610	
9	FE1	.000	.000	.000	.671	.000	.000	.550	
10	FE2	.000	.000	.000	.589	.000	.000	.654	
11	FF1	.000	.672	.000	.000	.000	.000	.548	>.399
12	FF2	.000	.513	.000	.000	.000	.000	.737	
13	FI1	.000	.269	.000	.414	.000	.000	.679	>.179
14	FI3	.000	.367	.000	.406	.000	.000	.597	
15	FW1	.000	.000	.000	.638	.000	.000	.593	
16	FW2	.000	.000	.000	.691	.000	.000	.523	
17	I1	.416	.000	.311	.000	.000	.196	.551	
18	I3	.409	.000	.000	.000	.000	.000	.833	
19	IP1	.344	.000	.000	.000	.000	.483	.537	
20	IP2	.343	.000	.000	.000	.000	.467	.557	
21	MA1	.000	.000	.000	.000	.889	.000	.210	
22	MA2	.000	.000	.000	.000	.813	.000	.340	
23	MS1	.000	.000	.000	.000	.000	.545	.703	>.407
24	MS3	.000	.000	.000	.000	.000	.495	.755	
25	MV2	.358	.000	.000	.000	.417	.000	.630	
26	MV3	.342	.000	.000	.000	.231	.000	.794	
27	N1	.000	.000	.929	.000	.000	.000	.137	
28	N3	.000	.000	.785	.000	.000	.000	.384	
29	P1	.000	.000	.548	.000	.000	.000	.699	>.199
30	P2	.000	.000	.482	.000	.000	.000	.767	
31	RG1	.472	.000	.188	.000	.000	.424	.342	
32	RG3	.429	.000	.000	.000	.000	.406	.534	
33	RL1	.193	.000	.000	.000	.000	.269	.855	>.087
34	RL2	.513	.000	.000	.000	.000	.309	.536	
35	S1	.612	.000	.000	.000	.000	.000	.625	
36	S2	.704	.000	.000	.000	.000	.000	.505	
37	SS1	.515	.000	.000	.000	.000	.000	.734	
38	SS3	.514	.000	.294	.000	.000	.000	.598	
39	V1	.000	.000	.000	-.052	.000	.706	.550	>.226
40	V2	.000	.000	.000	-.074	.000	.736	.530	
41	VZ2	.698	.000	.000	.000	.000	.000	.513	
42	VZ3	.804	.000	.000	.000	.000	.000	.354	
43	XF1	.528	.000	.000	.000	.000	.000	.721	
44	XF3	.653	.000	.000	.000	.000	.000	.573	
45	XU1	.311	.000	.000	.275	.000	.000	.766	
46	XU3	.290	.000	.000	.414	.000	.000	.657	

Table 19. (Concluded)

Factor Correlations

	1 Spatial Orientation	2 Figural Fluency	3 Number/ Speed	4 Verbal Fluency	5 Associative Memory	6 Verbal Memory
1 Spatial Orientation	1.000					
2 Figural Fluency	.164	1.000				
3 Number/Speed	.172	.235	1.000			
4 Verbal Fluency	.362	.344	.401	1.000		
5 Associative Memory	.228	.156	.318	.336	1.000	
6 Verbal Memory	.335	-.009	.347	.706	.294	1.000

The ASVAB School Attainment factor appears as mostly a function of the Kit Verbal factors, with an added Spatial Orientation component. The ASVAB Speed factor is generally a function of the Kit Number/Speed factor; the total combined effect of the regression weights due the Spatial and Verbal factors is negligible. The ASVAB Technical Knowledge factor shows positive effects from Kit Spatial Orientation and Figural Fluency, and a small negative effect from Number/Speed.

Table 20. Restricted Three-Factor ASVAB Model Regressed onto Six Major Kit Factors. Boundary Solution

ASVAB Factor Loadings and Uniqueness Coefficients

	1 School Attainment	2 Speed	3 Technical Knowledge	Residual Variance
1 GS	.729	.000	.000	.469
2 AR	.686	.477	.000	.309
3 WK	.684	.000	.000	.532
4 PC	.561	.000	.000	.686
5 NO	.000	.819	.000	.330
6 CS	.000	.744	.000	.447
7 AS	.000	.000	.707	.500
8 MK	.560	.485	.000	.457
9 MC	.000	.000	.824	.321
10 EI	.000	.000	.766	.413

Residual Correlation Components of ASVAB Factors

	School Attainment	Speed	Technical Knowledge
School Attainment	.000		
Speed	.000	.162	
Technical Knowledge	.000	.059	.138

Table 20. (Continued)

Regression Coefficients Relating ASVAB Factors to Kit Factors

	1 Spatial Orientation	2 Figural Fluency	3 Number/ Speed	4 Verbal Fluency	5 Associative Memory	6 Verbal Memory
School Attainment	.379	.111	-.171	-.847	-.025	1.508
Speed	.263	-.032	.729	.528	.135	-.630
Technical Knowledge	.680	.395	-.340	-1.106	-.156	1.182

Kit Factor Correlations

	1 Spatial Orientation	2 Figural Fluency	3 Number/ Speed	4 Verbal Fluency	5 Associative Memory	6 Verbal Memory
1 Spatial Orientation	1.000					
2 Figural Fluency	.159	1.000				
3 Number/Speed	.169	.254	1.000			
4 Verbal Fluency	.362	.376	.441	1.000		
5 Associative Memory	.232	.159	.307	.362	1.000	
6 Verbal Memory	.360	.114	.335	.881	.312	1.000

Factor Loadings for the Kit

	1 Spatial Orientation	2 Figural Fluency	3 Number/ Speed	4 Verbal Fluency	5 Associative Memory	6 Verbal Memory	Uniqueness Var.	Uniqueness Cov.
1 CF2	.595	.000	.000	.000	.000	.000	.646	
2 CF3	.733	.000	.000	.000	.000	.000	.463	
3 CS1	.393	.000	.000	.000	.000	.000	.845	>.214
4 CS2	.237	.000	.109	.224	.000	.000	.813	
5 CV1	.000	.000	.250	.428	.000	.000	.660	>.205
6 CV3	.000	.000	.240	.406	.000	.000	.692	
7 FA1	.000	.000	.000	.685	.000	.000	.530	
8 FA2	.000	.000	.000	.600	.000	.000	.640	
9 FE1	.000	.000	.000	.658	.000	.000	.567	
10 FE2	.000	.000	.000	.571	.000	.000	.674	
11 FF1	.000	.612	.000	.000	.000	.000	.626	>.433
12 FF2	.000	.507	.000	.000	.000	.000	.743	
13 FI1	.000	.258	.000	.391	.000	.000	.705	>.195
14 FI3	.000	.404	.000	.364	.000	.000	.593	
15 FW1	.000	.000	.000	.631	.000	.000	.602	

Table 20. (Concluded)

	1 Spatial Orientation	2 Figural Fluency	3 Number/ Speed	4 Verbal Fluency	5 Associative Memory	6 Verbal Memory	Uniqueness Var.	Uniqueness Cov.
16 FW2	.000	.000	.000	.676	.000	.000	.543	
17 I1	.408	.000	.324	.000	.000	.198	.544	
18 I3	.403	.000	.000	.000	.000	.000	.838	
19 IP1	.383	.000	.000	.000	.000	.409	.574	
20 IP2	.365	.000	.000	.000	.000	.415	.585	
21 MA1	.000	.000	.000	.000	.898	.000	.193	
22 MA2	.000	.000	.000	.000	.811	.000	.342	
23 MS1	.000	.000	.000	.000	.000	.524	.725	>.434
24 MS3	.000	.000	.000	.000	.000	.464	.785	
25 MV2	.361	.000	.000	.000	.409	.000	.634	
26 MV3	.343	.000	.000	.000	.228	.000	.794	
27 N1	.000	.000	.894	.000	.000	.000	.200	
28 N3	.000	.000	.814	.000	.000	.000	.337	
29 P1	.000	.000	.565	.000	.000	.000	.681	>.162
30 P2	.000	.000	.535	.000	.000	.000	.714	
31 RG1	.520	.000	.250	.000	.000	.319	.348	
32 RG3	.443	.000	.000	.000	.000	.372	.546	
33 RL1	.199	.000	.000	.000	.000	.253	.860	>.094
34 RL2	.520	.000	.000	.000	.000	.277	.550	
35 S1	.603	.000	.000	.000	.000	.000	.636	
36 S2	.697	.000	.000	.000	.000	.000	.515	
37 SS1	.514	.000	.000	.000	.000	.000	.736	
38 SS3	.539	.000	.239	.000	.000	.000	.609	
39 V1	.000	.000	.000	-.765	.000	1.387	.361	>.077
40 V2	.000	.000	.000	-.619	.000	1.250	.418	
41 VZ2	.692	.000	.000	.000	.000	.000	.521	
42 VZ3	.794	.000	.000	.000	.000	.000	.369	
43 XF1	.524	.000	.000	.000	.000	.000	.726	
44 XF3	.647	.000	.000	.000	.000	.000	.581	
45 XU1	.335	.000	.000	.237	.000	.000	.774	
46 XU3	.283	.000	.000	.400	.000	.000	.679	

IV. CONCLUSIONS

The study identified three major ASVAB factors and six major Kit factors. The Kit factors appear to encompass much of the variation found in the ASVAB factors. As a general rule, Spatial Kit components best predict the scores of technical ASVAB subtests, Verbal Memory components best predict School Attainment, and Kit scales related to Number/Speed best (and exclusively) predict the two speeded ASVAB tests related to clerical and numerical speed.

The Kit factor analyses consistently produced a Verbal Fluency component, in addition to the Verbal Memory factor. Though the results clearly show the need for a two-dimensional construct of verbal ability, the correlation between the two factors appeared to be rather unstable in the present study. Some future effort should be made to map the factor structure of the verbal domain more clearly. Verbal fluency appears to be a necessary aptitude for all successful writers, whereas the ability to retain verbal content in memory would affect performance in nearly all occupational fields.

It may be noted that the indicators of the Kit Spatial Orientation factor are all rather exclusively comprised of older spatial tasks that tend to permit solutions by non-analog (i.e., non-visualizing or non-image-manipulating) strategies (cf., Zimowski & Wothke, 1986). It is therefore not surprising that a number of clearly nonspatial reasoning tasks showed substantial loadings on this so-called Spatial Orientation factor. The spatial domain should, in future studies, be studied with analog spatial tests like the Vandenberg-Shepard Mental Rotations test.

Apart from these cautionary remarks, the study clearly identified Figural Fluency and Associative Memory as specific, but stable ability factors that are not at all addressed by the ASVAB. At the time of this writing we can only speculate what possible predictive validity the two new dimensions might have; but, judging from its content, one could easily imagine that Figural Fluency may be a rather important component in the production and understanding of technical and/or spatial information. A literature search would produce some prior validity studies of the pertinent tests. This information may give rise to further validity studies. Technical illustrators and electronic circuit board designers, for instance, would be important target groups.

It is a little harder to conjecture where Associative Memory may play an important role in job performance. Air controllers and a limited number of intelligence and communications tasks might currently be affected. Again, a literature search would provide a good amount of useful information. However, further validity testing for the mentioned occupations should proceed with care, for the occupational demands are currently in a process of rapid change due to the introduction of advanced technology into these areas.

REFERENCES

Allison, P. D. (1987). Estimation of linear models with incomplete data. In C. Clogg [Ed.] Sociological methodology, 1987. Washington, DC: American Sociological Association.

Anderson, J. C., & Gerbing, D. W. (1984). The effect of sampling error on convergence, improper solutions and goodness-of-fit indices for maximum likelihood confirmatory factor analysis. Psychometrika, 49(2), 155-173.

Anderson, T. W. (1984). An Introduction to multivariate statistical analysis (2nd ed.). New York: Wiley.

Anderson, T. W., & Rubin, H. (1956). Statistical inference in factor analysis. In J. Neyman [Ed.], Proceedings of the Third Berkeley Symposium on Mathematical Statistics and Probability. Berkeley: University of California Press.

Bock, R. D. (1975). Multivariate statistical methods for behavioral research. New York: McGraw-Hill.

Bock, R. D., & Moore, E. G. J. (1986). Advantage and disadvantage: A profile of the American youth. Hillsdale, NJ: Lawrence Earlbaum.

Bollen, K. A. (1989). Structural equations with latent variables. New York: Wiley.

Browne, M. W. (1980). Factor analysis of multiple batteries by maximum likelihood. British Journal of Mathematical and Statistical Psychology, 30, 113-124.

Bureau of Census. (1988). Statistical abstract of the United States. Washington, DC: U.S. Government Printing Office.

Department of Defense, (1983). Manual for administration, Armed Services Vocational Aptitude Battery. (DoD 1304.12A) Washington, DC: Author.

Ekstrom, R. B., French, J. W., Harman, H. H., with Derman, D. (1976a). ETS Kit of factor-referenced cognitive tests. Princeton, NJ: Educational Testing Service.

Ekstrom, R. B., French, J. W., Harman, H. H., with Derman, D. (1976b). Manual for Kit of factor-referenced cognitive tests. Princeton, NJ: Educational Testing Service.

Hauser, R. M., & Goldberger, A. S. (1971). The treatment of unobservable variables in path analysis. In H. L. Costner (Ed.), Sociological Methodology, (pp. 81-117) San Francisco, C. A. Jossey-Bass.

Hendrickson, A. E., & White, P. O. (1964). Promax: a quick method for rotation to oblique simple structure. British Journal of Mathematical and Statistical Psychology, 17, 65-70.

Hunter, J. E., Crosson, J. J., & Friedman, D. H. (1985). The validity of the Armed Services Vocational Aptitude Battery (ASVAB) for civilian and military job performance (Contract No. F41689-83-C-0025). Washington, DC: HQ USAF/MPXOA, Department of Defense.

Joreskog, K. G., & Sorbom, D. (1989). LISREL 7 User's reference guide. Mooresville, IN: Scientific Software, Inc.

Kendall, M., & Stuart, A. (1977). The advanceu 'heory of statistics: Vol. 1. Distribution theory. London, GB: Charles Griffin.

Palmer, P., Haywood, C. S., Fairbank, B. A., & Earles, J. A. (1990). Comparison of the Armed Services Vocational Aptitude Battery to the General Aptitude Test Battery (AFHRL-TP-90-8, AD-A221 551). Brooks AFB, TX: Manpower and Personnel Division, Air Force Human Resources Laboratory.

Ree, M. J., Mullins, C. J., Mathews, J. J., & Massey, R. H. (1982). Armed Services Vocational Aptitude Battery: Item and factor analyses of Forms 8, 9, and 10 (AFHRL-TR-81-55, AD-A113 465). Brooks AFB, TX: Manpower and Personnel Division, Air Force Human Resources Laboratory.

Welsh, J. R., Jr., Kucinkas, S. K., & Curran, L. (1990). Armed Service Vocational Aptitude Battery (ASVAB): Integrative review of validity studies (AFHRL-TR-90-22, AD-A225 074). Brooks AFB, TX: Manpower and Personnel Division, Air Force Human Resources Laboratory.

Zimowski, M. F., & Wothke, W. (1986). The Measurement of human variation in spatial visualizing ability: A Process-oriented perspective Chicago, IL: Johnson O'Connor Research Foundation. (Also: Washington, DC: U.S. Dept. of Ed., Educational Resources Information Center, TM 012 916).

APPENDIX A: FACTOR-REFERENCED TEST SCORING CATEGORIES

Category 1: Tests with objective test items and comprehensive answer keys. Letters or numbers must occasionally be deciphered.

CF-2 -- Hidden Patterns Test
CS-2 -- Concealed Words Test
I-1 -- Letter Sets Test
I-3 -- Figure Classification Test
IP-1 -- Calendar Test
IP-2 -- Following Directions Test
MA-1 -- Picture-Number Test
MA-2 -- Object-Number Test
MS-1 -- Auditory Number Span Test
MS-3 -- Auditory Letter Span Test
MV-2 -- Building Memory Test
MV-3 -- Map Memory Test
N-1 -- Addition Test
N-3 -- Subtraction & Multiplication Test
P-1 -- Finding A's Test
P-2 -- Number Comparison Test
RG-1 -- Arithmetic Aptitude Test
RG-3 -- Necessary Arithmetic Operations Test
RL-1 -- Nonsense Syllogisms Test
RL-2 -- Diagramming Relationships Test
S-1 -- Card Rotations Test
S-2 -- Cube Comparisons Test
SS-1 -- Maze Tracing Speed Test
SS-3 -- Map Planning Test
V-1 -- Vocabulary I Test
V-2 -- Vocabulary II Test
VZ-2 -- Paper Folding Test
VZ-3 -- Surface Development Test
XF-3 -- Storage Test

Category 2: Tests with noncomprehensive answer keys. Items may have several acceptable solutions or answers. Marks or handwriting must often be deciphered.

CF-3 -- Copying Test
CS-1 -- Gestalt Completion Test
CV-1 -- Scrambled Words Test
CV-3 -- Incomplete Words Test
FA-1 -- Controlled Associations Test
FA-2 -- Opposites Test
FW-1 -- Word Endings Test
FW-2 -- Word Beginnings Test
XF-1 -- Toothpicks Test
XU-1 -- Combining Objects Test

Category 3: Open-ended test items without answer keys. Substantial scorer judgment is required and deciphering of handwriting is often necessary.

FE-1 -- Making Sentences Test
FE-2 -- Arranging Words Test
FF-1 -- Ornamentation Test
FF-2 -- Elaboration Test
FI-1 -- Topics Test
FI-3 -- Thing Categories Test
XU-3 -- Making Groups Test

APPENDIX B: UNIVARIATE STATISTICS AND PAIRWISE CORRELATIONS

Univariate Summary Statistics for Continuous Variables

Variable	Mean	Standard Deviation	Skewness	Kurtosis
AGE	20.386	2.372	1.640	3.680
EDUCATION	.232	.471	.627	-.134
POPULATION	.133	.339	2.164	2.681
SEX	.169	.375	1.767	1.121
GS	17.760	3.623	-.149	-.490
AR	19.752	5.535	-.097	-.749
WK	29.166	3.868	-.833	.926
PC	12.150	2.067	-1.090	1.641
NO	40.315	7.882	-.719	.171
CS	54.859	12.218	.055	.017
AS	16.752	4.546	-.258	-.766
MK	15.730	5.046	-.079	-.915
MC	16.579	4.519	-.337	-.595
EI	13.174	3.277	-.267	-.290
RG1	11.592	5.747	.305	-.328
N1	33.944	10.015	.439	.341
FA2	20.109	5.164	.167	.223
MS1	7.318	3.082	.465	.269
CV3	18.541	5.978	-.205	-.181
XU3	15.234	4.147	-.266	.751
RL1	5.050	4.613	1.246	1.683
V2	15.998	5.307	.110	.164
RG3	11.762	5.167	.203	-.285
MA1	20.380	10.192	.198	-.895
S2	15.434	9.136	.315	-.507
FI1	22.408	8.331	.732	1.130
I1	18.342	5.697	-.682	.138
VZ2	10.173	4.408	-.301	-.254
P1	56.185	14.582	.499	.400
SS3	22.552	7.607	-.372	.245
FW1	28.467	7.746	.156	.130
FE1	14.525	3.835	-.646	-.072
MA2	10.611	6.781	.778	-.055
MV2	14.902	5.503	-.389	-.519
RL2	11.881	6.605	.449	-.514
XF3	5.846	5.494	.592	-.601
V1	18.837	6.719	.010	-.141
P2	47.942	12.315	.123	.822
FF1	27.171	9.831	.299	-.776
FW2	19.207	6.596	.612	.740
S1	104.372	34.156	-1.063	1.124
I3	111.998	32.861	-.229	-.118
XU1	20.303	5.926	-.381	.108
IP2	9.526	4.234	.085	-.413
N3	47.141	16.610	.721	.817
CS1	13.359	3.155	-.734	.612

Variable	Mean	Standard Deviation	Skewness	Kurtosis
CF2	171.106	55.613	-.744	.522
FE2	6.541	3.266	.455	.675
MV3	18.124	5.065	-.867	.127
FI3	16.926	5.405	.782	3.115
IP1	11.706	4.065	-.138	-.614
VZ3	31.691	14.238	.161	-.873
FF2	19.585	8.178	.572	-.367
CF3	26.531	9.325	.392	.105
SS1	27.392	6.919	.385	.301
CS2	26.229	7.320	-.036	-.264
MS3	5.697	2.112	.715	1.549
FA1	19.216	7.260	.688	1.104
CV1	43.890	6.653	-1.647	2.757
XF1	7.061	4.601	.841	.753

Estimated correlation matrix, based on pairwise deletion of missing data.

Estimated Correlation Matrix - Part I

	Age	Education	Population	Sex	GS	AR
AGE	1.000					
EDUCATION	.439	1.000				
POPULATION	.048	.088	1.000			
SEX	.014	.057	.084	1.000		
GS	.105	.161	-.253	-.198	1.000	
AR	.030	.133	-.227	-.137	.438	1.000
WK	.174	.166	-.154	-.037	.550	.362
PC	.084	.104	-.132	.016	.326	.408
NO	-.010	.140	-.006	.127	.000	.302
CS	.025	.109	-.091	.251	.022	.239
AS	.142	.006	-.323	-.442	.438	.304
MK	-.036	.232	-.054	.034	.384	.649
MC	.060	.055	-.325	-.298	.471	.460
EI	.143	.092	-.246	-.377	.564	.378
RG1	.047	.132	-.249	-.097	.470	.815
N1	.074	.090	-.043	.096	.104	.422
FA2	.022	.080	-.021	.097	.242	.317
MS1	.051	.085	.006	.028	.214	.361
CV3	-.031	.074	.056	.148	.145	.404
XU3	-.076	.032	-.127	.113	.232	.432
RL1	.027	.085	-.055	-.022	.309	.323
V2	.165	.216	-.085	.047	.578	.272

Estimated Correlation Matrix - Part 1 (Concluded)

	Age	Education	Population	Sex	GS	AR
RG3	-.029	.121	-.186	-.045	.479	.628
MA1	-.014	.120	-.005	.105	-.061	.235
S2	-.060	.034	-.201	-.159	.234	.467
FI1	-.026	.061	-.086	.069	.061	.241
I1	-.060	.093	-.085	.088	.109	.494
VZ2	-.102	-.044	-.232	-.215	.336	.495
P1	.039	.090	.179	.238	-.079	.077
SS3	- 176	-.031	-.194	-.087	.151	.326
FW1	.017	.112	.047	.133	.098	.251
FE1	-.055	.082	-.091	.158	.241	.257
MA2	-.033	.058	-.028	.088	.142	.269
MV2	-.067	.052	-.197	.036	.148	.299
RL2	-.011	.136	-.159	-.008	.391	.546
XF3	-.064	.031	-.201	-.140	.330	.397
V1	.186	.155	-.116	.047	.507	.306
P2	.078	.128	.034	.190	.046	.081
FF1	-.051	.033	.049	-.029	.090	.038
FW2	.099	.163	.010	.111	.274	.353
S1	-.053	-.006	-.198	-.159	.236	.282
I3	-.100	.036	-.139	-.002	.183	.213
XU1	-.032	.042	-.238	-.100	.262	.296
IP2	.064	.134	-.148	-.025	.380	.547
N3	.007	.098	.012	.071	-.188	.189
CS1	-.037	-.020	-.187	-.116	.257	.216
CF2	-.024	.046	-.204	-.039	.282	.313
FE2	-.101	.008	-.090	.061	.172	.137
MV3	-.012	-.009	-.146	-.014	.335	.309
FI3	.010	.100	-.070	.060	.149	.209
IP1	.032	.099	-.177	.036	.372	.574
VZ3	-.041	.041	-.275	-.076	.388	.554
FF2	.058	.087	.068	-.016	-.031	.085
CF3	-.031	.055	-.234	-.125	.188	.388
SS1	-.185	-.041	-.126	-.073	.061	.073
CS2	.023	.083	-.017	-.081	.111	.358
MS3	.029	.075	-.002	.097	.090	.155
FA1	.061	.138	-.073	.107	.305	.269
CV1	-.045	.063	-.027	.148	.029	.239
XF1	-.042	-.008	-.197	-.078	.238	.419

Estimated Correlation Matrix - Part 2

	WK	PC	NO	CS	AS	MK
WK	1.000					
PC	.433	1.000				
NO	.043	.173	1.000			
CS	.041	.189	.632	1.000		
AS	.222	.221	-.133	-.134	1.000	
MK	.298	.377	.394	.306	.083	1.000
MC	.306	.235	-.026	-.029	.600	.331
EI	.370	.216	-.041	-.061	.595	.264
RG1	.464	.489	.392	.242	.238	.652
N1	.183	.272	.544	.525	-.226	.383
FA2	.422	.299	.196	.156	-.019	.360
MS1	.275	.278	.187	.242	.039	.314
CV3	.286	.406	.281	.299	-.229	.370
XU3	.323	.300	.264	.192	.118	.411
RL1	.280	.171	.073	.019	.120	.218
V2	.616	.353	.144	.112	.164	.430
RG3	.374	.395	.301	.234	.164	.531
MA1	.064	.214	.278	.304	-.123	.359
S2	.133	.191	.123	.092	.222	.330
FI1	.157	.269	.145	.200	-.028	.131
I1	.078	.304	.310	.300	-.034	.497
VZ2	.213	.196	.004	.065	.247	.372
P1	.081	.061	.267	.399	-.214	.190
SS3	.118	.254	.177	.218	.237	.343
FW1	.230	.156	.312	.228	-.050	.360
FE1	.377	.298	.282	.286	-.014	.292
MA2	.140	.160	.210	.204	-.096	.349
MV2	.131	.143	.157	.255	.138	.276
RL2	.348	.337	.210	.161	.122	.522
XF3	.332	.217	.067	.034	.401	.292
V1	.676	.301	-.122	-.027	.101	.264
P2	-.005	.108	.362	.490	-.213	.159
FF1	.007	.034	.197	.173	.003	.097
FW2	.343	.264	.229	.159	-.134	.283
S1	.217	.232	.053	.168	.238	.323
I3	.048	.016	.161	.228	.058	.026
XU1	.149	.128	.082	.138	.295	.164
IP2	.441	.466	-.003	.127	.154	.460
N3	-.107	-.042	.622	.499	-.189	.288
CS1	.269	.124	.005	.093	.170	.128
CF2	.175	.250	.301	.267	.166	.319
FE2	.128	.167	.298	.168	-.032	.294
MV3	.213	.233	.232	.250	.122	.260
FI3	.156	.122	.211	.132	.139	.243
IP1	.402	.295	.273	.291	.218	.486
VZ3	.321	.217	.075	.147	.351	.482
FF2	-.005	.047	.294	.197	-.003	.080
CF3	.046	.094	.318	.298	.208	.369

Estimated Correlation Matrix - Part 2 (Concluded)

	WK	PC	NO	CS	AS	MK
SS1	-.065	-.104	.260	.240	.169	.193
CS2	.088	.132	.165	.087	.138	.248
MS3	.263	.202	.171	.104	.038	.282
FA1	.320	.217	.234	.146	.060	.384
CV1	.026	.163	.245	.236	-.076	.332
XF1	.081	.066	.048	.096	.178	.266

Estimated Correlation Matrix - Part 3

	MC	EI	RG1	N1	FA2	MS1
MC	1.000					
EI	.563	1.000				
RG1	.365	.352	1.000			
N1	-.137	-.091	.428	1.000		
FA2	.075	.110	.239	.166	1.000	
MS1	.074	.087	.324	.267	.266	1.000
CV3	-.067	-.076	.265	.360	.302	.295
XU3	.273	.217	.347	.217	.346	.187
RL1	.185	.224	.290	.103	.196	.208
V2	.223	.418	.356	.069	.348	.220
RG3	.377	.292	.632	.194	.218	.109
MA1	.017	-.047	.178	.167	.163	.064
S2	.434	.238	.425	.103	.188	.058
FI1	.061	.082	.288	.234	.319	.253
I1	.229	.096	.503	.320	.173	.286
VZ2	.515	.361	.555	-.039	.090	.045
P1	-.056	-.127	.166	.331	.134	.164
SS3	.412	.297	.410	.383	.189	.296
FW1	.086	.041	.274	.276	.286	.268
FE1	.061	-.005	.280	.294	.341	.252
MA2	.003	-.080	.276	.160	.117	.234
MV2	.278	.091	.252	.163	.138	.221
RL2	.372	.293	.448	.163	.294	.121
XF3	.529	.444	.306	-.007	.136	.047
V1	.301	.281	.301	.046	.449	.237
P2	-.068	-.130	.158	.295	.139	.061
FF1	.055	.016	.193	.250	.154	.120
FW2	.050	.006	.305	.243	.456	.241
S1	.378	.228	.377	.161	.160	.256
I3	.145	.066	.248	.142	.116	.094
XU1	.335	.328	.252	.097	.373	.033
IP2	.419	.286	.518	.227	.314	.375
N3	-.141	-.089	.435	.788	.077	.354
CS1	.282	.279	.164	-.031	.170	-.063

Estimated Correlation Matrix - Part 3 (Concluded)

	MC	EI	RG1	N1	FA2	MS1
CF2	.276	.235	.360	.171	.198	.129
FE2	.131	.138	.205	.182	.353	.191
MV3	.253	.155	.251	.139	.267	.116
FI3	.109	.170	.291	.252	.353	.202
IP1	.422	.319	.362	.248	.258	.309
VZ3	.541	.392	.418	.087	.190	-.001
FF2	-.060	.098	-.026	.155	-.002	.026
CF3	.349	.187	.376	.122	.195	.072
SS1	.252	.099	.105	.094	.064	.064
CS2	.251	.106	.084	.113	.133	.108
MS3	.116	.126	.237	.170	.378	.677
FA1	.302	.167	.297	.223	.588	.249
CV1	.070	-.037	.274	.304	.268	.327
XF1	.249	.162	.368	.037	.107	.052

Estimated Correlaiton Matrix - Part 4

	CV3	XU3	RL1	V2	RG3	MA1
CV3	1.000					
XU3	.213	1.000				
RL1	.153	.166	1.000			
V2	.239	.275	.204	1.000		
RG3	.208	.296	.211	.340	1.000	
MA1	.144	.172	.129	.126	.231	1.000
S2	.127	.333	.124	.173	.398	.130
FI1	.148	.427	.037	.185	.196	.206
I1	.336	.408	.101	.245	.424	.303
VZ2	.089	.222	.123	.162	.382	.102
P1	.375	.175	-.001	.022	.097	.213
SS3	.274	.425	.143	.159	.387	.190
FW1	.421	.277	.109	.280	.235	.218
FE1	.287	.395	.113	.321	.259	.150
MA2	.222	.145	.103	.109	.201	.691
MV2	.154	.220	.102	.196	.320	.457
RL2	.195	.410	.335	.282	.491	.210
XF3	.040	.166	.257	.259	.346	.029
V1	.224	.286	.071	.685	.243	.070
P2	.207	.076	.104	.043	.238	.204
FF1	.037	.153	.058	.035	.175	.158
FW2	.466	.241	.224	.434	.343	.210
S1	.098	.430	.211	.054	.306	.046
I3	.059	.201	.140	.099	.187	.041
XU1	.161	.437	.067	.158	.293	.059
IP2	.217	.370	.187	.408	.491	.243
N3	.390	.244	.175	.086	.233	.290

Estimated Correlation Matrix - Part 4 (Concluded)

	CV3	XU3	RL1	V2	RG3	MA1
CS1	.194	.202	.161	.190	.070	.021
CF2	.085	.315	.171	.130	.281	.116
FE2	.217	.357	.173	.146	.115	.182
MV3	.214	.254	.117	.105	.230	.279
FI3	.232	.428	.267	.128	.106	.145
IP1	.233	.441	.334	.324	.401	.189
VZ3	.049	.297	.308	.246	.412	.115
FF2	.123	-.059	.026	-.086	.041	-.029
CF3	.195	.279	.220	.253	.361	.141
SS1	.077	.199	.156	.072	.242	.121
CS2	.448	.069	.100	.227	.150	.220
MS3	.160	.003	.162	.247	.305	.165
FA1	.263	.373	.162	.333	.335	.275
CV1	.529	.187	.209	.293	.274	.237
XF1	.069	.172	.298	.183	.238	.163

Estimated Correlation Matrix - Part 5

	S2	FI1	I1	VZ2	P1	SS3
S2	1.000					
FI1	.114	1.000				
I1	.392	.202	1.000			
VZ2	.490	.103	.354	1.000		
P1	.136	.096	.230	.015	1.000	
SS3	.359	.195	.362	.294	.213	1.000
FW1	.157	.193	.402	.150	.281	.179
FE1	.210	.306	.290	.144	.172	.235
MA2	.160	.234	.195	.199	.145	.136
MV2	.270	.117	.420	.351	.113	.323
RL2	.488	.180	.551	.423	.088	.354
XF3	.463	.058	.327	.502	.015	.332
V1	.120	.096	.185	.125	-.057	.109
P2	.208	.116	.201	.086	.464	.212
FF1	.105	.354	.093	.041	.142	-.026
FW2	.172	.417	.430	.073	.230	.071
S1	.445	.073	.167	.345	.001	.376
I3	.335	.070	.178	.223	.127	.288
XU1	.382	.279	.243	.419	.030	.163
IP2	.427	.194	.477	.257	.029	.326
N3	.062	.203	.210	-.010	.377	.241
CS1	.288	.032	.169	.352	.026	.185
CF2	.341	.112	.362	.380	.252	.416
FE2	.209	.469	.178	.051	.129	.244
MV3	.263	.147	.271	.233	-.035	.249
FI3	.240	.536	.211	.136	.101	.147
IP1	.329	.164	.435	.378	.132	.390

Estimated Correlation Matrix - Part 5 (Concluded)

	S2	FI1	I1	VZ2	P1	SS3
VZ3	.568	.159	.388	.624	.069	.485
FF2	-.023	.094	-.068	-.063	.131	.068
CF3	.506	.127	.371	.464	.152	.414
SS1	.292	.115	.216	.341	.209	.402
CS2	.265	.036	.342	.329	.142	.284
MS3	.174	.216	.299	.174	.087	.152
FA1	.217	.391	.341	.226	.176	.249
CV1	.239	.030	.390	.216	.311	.259
XF1	.328	.076	.280	.447	.017	.434

Estimated Correlation Matrix - Part 6

	FW1	FE1	MA2	MV2	RL2	XF3
FW1	1.000					
FE1	.424	1.000				
MA2	.216	.182	1.000			
MV2	.117	.154	.423	1.000		
RL2	.259	.276	.184	.342	1.000	
XF3	.130	.147	.112	.296	.430	1.000
V1	.193	.256	.019	.019	.381	.204
P2	.127	.123	.107	.100	-.052	-.032
FF1	.128	.231	.129	.057	-.043	-.023
FW2	.453	.422	.090	-.075	.187	-.038
S1	.022	.134	.025	.266	.173	.341
I3	.098	.144	.014	.086	.195	.281
XU1	.257	.300	.046	.012	.254	.213
IP2	.242	.265	.151	.188	.406	.320
N3	.304	.262	.147	.011	.128	-.050
CS1	.004	.001	.087	.230	.230	.228
CF2	.209	.266	.150	.321	.326	.315
FE2	.369	.517	.170	.065	.097	.065
MV3	-.009	.050	.242	.381	.216	.273
FI3	.303	.286	.054	-.013	.119	.084
IP1	.225	.282	.163	.249	.482	.335
VZ3	.071	.168	.116	.438	.481	.565
FF2	.070	.222	.112	-.001	.043	-.054
CF3	.187	.357	.088	.235	.305	.483
SS1	.242	.301	.111	.241	.210	.324
CS2	.171	.284	.177	.224	.278	.216
MS3	.375	.273	.167	.216	.257	.126
FA1	.524	.427	.273	.174	.283	.225
CV1	.419	.332	.216	.262	.302	.230
XF1	.133	.184	.153	.294	.372	.395

Estimated Correlation Matrix - Part 7

	V1	P2	FF1	FW2	S1	I3
V1	1.000					
P2	-.024	1.000				
FF1	-.078	.129	1.000			
FW2	.394	.155	.129	1.000		
S1	.129	.193	.048	.111	1.000	
I3	.051	.143	.108	.050	.262	1.000
XU1	.208	.069	.196	.220	.248	.250
IP2	.363	.111	-.006	.307	.303	.175
N3	.020	.449	.224	.271	.097	.195
CS1	.277	.042	-.072	.235	.183	.133
CF2	.184	.136	.016	.149	.438	.239
FE2	.158	.140	.051	.264	.201	.257
MV3	.272	.100	-.088	.114	.287	.179
FI3	.127	.108	.169	.355	.008	.252
IP1	.448	.148	-.113	.272	.309	.231
VZ3	.292	.099	-.081	.220	.504	.414
FF2	.047	.053	.743	.178	.167	-.018
CF3	.204	.246	.141	.234	.585	.247
SS1	.067	.180	.143	.100	.355	.274
CS2	.241	.130	.014	.326	.184	.114
MS3	.200	.114	.213	.253	.194	.019
FA1	.340	.024	.161	.527	.097	.075
CV1	.131	.253	-.047	.339	.181	.006
XF1	.119	.176	-.100	.266	.331	.198

Estimated Correlation Matrix - Part 8

	XU1	IP2	N3	CS1	CF2	FE2
XU1	1.000					
IP2	.233	1.000				
N3	.059	.117	1.000			
CS1	.106	.207	-.113	1.000		
CF2	.223	.277	.158	.239	1.000	
FE2	.324	.202	.199	.033	.243	1.000
MV3	.240	.308	.006	.182	.230	.160
FI3	.230	.102	.178	.084	.202	.363
IP1	.253	.597	.166	.130	.300	.229
VZ3	.313	.448	-.005	.382	.432	.171
FF2	.216	-.014	.186	.022	.112	.224
CF3	.225	.414	.123	.269	.385	.224
SS1	.266	.206	.129	.230	.331	.295
CS2	.228	.252	.114	.346	.216	.166
MS3	.110	.228	.204	.005	.009	.254
FA1	.350	.325	.205	.005	.231	.310
CV1	.220	.325	.359	.054	.259	.278
XF1	.145	.256	.038	.184	.342	.125

Estimated Correlation Matrix - Part 9

	MV3	FI3	IP1	VZ3	FF2	CF3
MV3	1.000					
FI3	.091	1.000				
IP1	.252	.173	1.000			
VZ3	.276	.142	.419	1.000		
FF2	-.091	.399	.038	.029	1.000	
CF3	.138	.203	.273	.463	.127	1.000
SS1	.151	.191	.151	.423	.173	.471
CS2	.109	.111	.171	.217	.008	.304
MS3	.081	.232	.291	.147	.067	.115
FA1	.099	.391	.335	.197	.132	.253
CV1	.120	.203	.315	.204	.048	.185
XF1	.132	.106	.272	.459	-.002	.359

Estimated Correlation Matrix - Part 10

	SS1	CS2	MS3	FA1	CV1	XF1
SS1	1.000					
CS2	.145	1.000				
MS3	.042	.159	1.000			
FA1	.144	.207	.262	1.000		
CV1	.102	.330	.264	.287	1.000	
XF1	.239	.150	.083	.168	.190	1.000

APPENDIX C: UNIVARIATE AND BIVARIATE SAMPLE SIZES

	AGE	EDUCATION	BK 1	BK 2	BK 3	BK 4	BK 5	BK 6	BK 7	BK 8
AGE	6015									
EDUCATION	6015	6751								
BOOK 1	1337	2055	2055							
BOOK 2	1345	2057	701	2057						
BOOK 3	1530	1536	225	222	1536					
BOOK 4	1587	1593	237	229	221	1593				
BOOK 5	1585	1595	229	229	223	233	1594			
BOOK 6	1539	1542	216	220	217	228	223	1542		
BOOK 7	1528	1533	218	226	207	214	227	215	1533	
BOOK 8	1571	1582	229	230	219	230	229	218	226	1582

APPENDIX D: MODELED STANDARD DEVIATIONS AND CORRELATION STRUCTURE FOR THE AFQT-1, AFQT-2, AND VE SCALES

Standard Deviations

1	AFQT-1	10.6989
2	AFQT-2	12.7609
3	VE	5.1140

Correlation Structure

			1 AFQT-1	2 AFQT-2	3 VE
	1	AFQT-1	1.000		
	2	AFQT-2	.923	1.000	
	3	VE	.743	.740	1.000
	4	AGE	.092	.065	.166
	5	EDUCATION	.200	.216	.168
	6	POPULATION	-.201	-.188	-.170
	7	SEX	-.035	-.055	-.021
	8	GS	.488	.561	.547
	9	AR	.838	.866	.438
	10	WK	.648	.648	.931
	11	PC	.625	.619	.732
	12	NO	.574	.328	.103
ASVAB	13	CS	.408	.268	.107
	14	AS	.231	.268	.257
	15	MK	.662	.828	.378
	16	MC	.384	.461	.326
	17	EI	.356	.415	.367
	18	RG1	.828	.831	.548
	19	N1	.537	.434	.248
	20	FA2	.446	.456	.440
	21	MS1	.409	.409	.320
	22	CV3	.494	.474	.380
	23	XU3	.495	.496	.365
	24	RL1	.328	.339	.281
	25	V2	.485	.532	.609
	26	RG3	.647	.660	.442
KIT	27	MA1	.289	.298	.135
	28	S2	.372	.405	.178
	29	FI1	.287	.248	.228
	30	I1	.457	.484	.182
	31	VZ2	.373	.459	.240
	32	P1	.179	.143	.086

			1	2	3
			AFQT-1	AFQT-2	VE
	33	SS3	.326	.354	.192
	34	FW1	.358	.346	.237
	35	FE1	.431	.389	.405
	36	MA2	.298	.323	.171
	37	MV2	.287	.302	.157
	38	RL2	.551	.604	.399
	39	XF3	.392	.423	.339
	40	V1	.416	.491	.633
	41	P2	.195	.114	.040
	42	FF1	.101	.063	.019
	43	FW2	.442	.412	.366
	44	S1	.289	.354	.258
	45	I3	.190	.120	.043
	46	XU1	.262	.259	.164
	47	IP2	.531	.628	.522
	48	N3	.280	.157	-.097
KIT	49	CS1	.235	.246	.253
	50	CF2	.384	.355	.233
	51	FE2	.259	.241	.164
	52	MV3	.367	.339	.256
	53	FI3	.266	.254	.167
	54	IP1	.600	.611	.423
	55	VZ3	.472	.563	.330
	56	FF2	.159	.074	.015
	57	CF3	.352	.343	.073
	58	SS1	.090	.071	-.091
	59	CS2	.303	.301	.120
	60	MS3	.278	.291	.281
	61	FA1	.383	.401	.330

* U. S. GOVERNMENT PRINTING OFFICE: 1991--761-052, 40030